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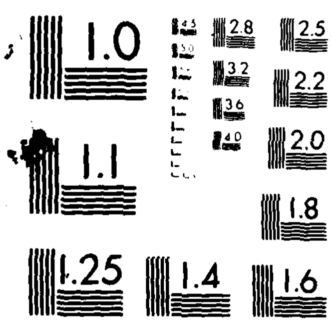

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MICROCIRCUIT COST FACTORS

Hughes Aircraft Company

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A life cycle cost (LCC) model for estimating differences in microcircuit (MC) devices was developed based on parametric cost estimating relationships (CER's) and user provided data. By analyzing the impact in characteristics of a family of MC devices on the LCC, a computer program was developed to provide a guide for selecting optimal MC characteristics that minimize the LCC for a total system procurement.

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Section 0.0

FOREWORD

A methodology is developed in this report for assessing the life cycle cost (LCC) impacts of microcircuit (MC) devices on system design, production and lifetime support. The methodology is based on the development of parametric cost-estimating-relationships (CER's) which relate specific MC characteristics (eg, reliability grade, packaging, complexity, technology, etc.) to costs that are incurred of various phases of system development, manufacturing, and maintenance and support. The data used to develop the CER's was compiled from Hughes' historical data files, literature searches, and government sources.

A computerized LCC model is provided which aggregates costs based on a set of MC characteristics and summarizes the results into the major cost elements of each program phase. A typical application of the methodology would be to compare the LCC of competing families of MC devices in the design implementation stage of system development. The level of integration (i.e., SSI/MSI vs. LSI vs. custom LSI), for example, would effect design partitioning which determines the number and types of circuit card assemblies to inventory and provide as spares during system maintenance and support.

Finally, a step-by-step guide is provided for using the LCC model which details the input requirements and default options, and describes the various outputs of the computer printout. Example applications of this model are also provided which involve: to MC tradeoffs of device quantity level, inhouse screening vs. vendor qualification, and custom LSI vs. standard SSI/MSI.

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The objective of this study was to develop parametric cost estimating relationships for guidance in selecting microcircuits that are intended for utilization in maintainable equipments operating in military environments. Cost relationships were developed and formatted in a comprehensive computerized model that provides a measure of relative impact that technology, function, package complexity and quality/reliability have on system Life Cycle Cost (LCC). The major LCC phases affected by microcircuits; development, production and maintenance, each has been accounted for in the model. Model users can input their specific data or default options are provided when the required inputs are unavailable.

The following microcircuit factors were found to have a measurable impact on system LCC:

Technology - Primary impact on material procurement cost.

Function - Strong influences on both material procurement and assembly cost.

Package - Material procurement and assembly costs are greater for flat-packages than for dual-in-line.

Complexity - Increased complexity, particularly for custom circuits have a noticeable impact on material and assembly cost. Test costs are significantly increased when linear microcircuit complexity is increased.

Quality/Reliability - Higher quality devices increased material cost and reduced assembly cost through less rework.

The resulting microcircuit cost factor model is applicable primarily to monolithic devices that represent today's technology. Updating of the model will be necessary to accomodate hybrids, technology evolution and testing improvements, as they are introduced. The model has been exercised using primarily the study contractors data set; additional verification will therefore be necessary before general purpose use can be recommended. The ultimate mechanism for distributing this model, once verification has been satisfactorily accomplished, will be the RADC Reliability Design Handbook.

Edward P. O'Connell
EDWARD P. O'CONNELL

Project Engineer

Section 1.0

SUMMARY OF STUDY RESULTS

1.1 INTRODUCTION

The extensive use of microcircuits (MC's) of all types and complexities in military electronic systems necessitates a close examination of the cost impact of these devices when alternate equipment designs, modifications, etc. are under consideration. Decisions on whether to use standard or custom MC's, JAN B or B-2 reliability grade, bipolar or MOS memory etc. can have far reaching impacts on the costs of system development, production and lifetime maintenance and support. Accordingly, the objectives of the study are to 1) analyze the cost factors associated with MC characteristics (i.e., type, complexity, packaging, technology, etc.), 2) develop parametric cost estimating relationships (CER's) based on relevant MC characteristics and 3) provide an application guide for selecting optimal (i.e., least cost) MC characteristics for use in military equipments.

Hughes adopted a "systems" approach in deriving CER's which would account for the major cost impacts resulting from changes in MC characteristics. In this systems approach, the entire population of a family of candidate MC devices is used to assess the life cycle cost (LCC) impact. A change from one family of devices to another not only has a direct effect on the MC population cost and, therefore, the system cost, but also has many "hidden" cost effects that are not generally accounted for in cost tradeoffs. Some of the major cost areas impacted by MC changes are given in Table 1.1-1.

The extent of the cost impact is, of course, a direct function of the MC device population effected by the change. Thus, if the effected population is large only a small change in MC characteristics could lead to a significant difference in LCC. In small populations (i.e., involving less than 100 devices), however, it is doubtful that the difference in LCC would be of any significance regardless of the change in MC characteristics.

1.2 MC DEVICE MODEL DESCRIPTION, GROUND RULES AND ASSUMPTIONS

The algorithm developed for estimating MC LCC consists of CER's derived from data gathered on device development and procurement, card and system

Table 1.1-1. Major LCC Areas Effected by MC Differences

Major Cost Area	Typical Causes Related to MC Differences
Card Production	Differences in device type (linear, digital), complexity, quality grade have an effect on assembly and test labor, and on test yield (which is the card production cost driver in the test-rework cycle.)
Sparing	Differences in device complexity generally effects the unit cost, and system re-partitioning which changes the number of card types. Changes in device quality grade impacts the quality of spares per operating site and the pipeline.
Depot Maintenance	The repair labor and materials cost is directly effected by differences in device complexity and quality grade.
Inventory and Supply Management	These costs are effected whenever new items, e.g., custom LSI) are introduced into government inventory. If the device complexity is changed and causes a re-partitioning of the system, a very significant cost impact could result.

manufacture and from system maintenance support. The cost impact of a family of MC devices over the life cycle (y) of a program is represented by the following model:

$$LCC_{MC}(y) = RCER + \sum_{i=1}^{4} PCER_i + \sum_{i=1}^{6} MCER_i(y) \quad (1.1)$$

Each of the cost factors in (1.1) represent a CER and is described in Table 1.2-1. The sources of data and methodology for processing the data are provided in Section 2 and a complete discussion of the CER's is given in Section 3 with examples illustrating the LCC model application given in Section 4.

A computer program was developed for the LCC model as a tool for performing trade-off analyses involving multiple changes in MC device characteristics. The computer program is written in ANSI FORTRAN IV and is documented in Appendix C. The program provides a number of input default options which are exercised when the user does not have the required data. For example, the CER's for some of the cost areas consist of a "basic" equation plus alternate equations based on a reduced set of MC variables. The "basic" equations provide the best (in terms of statistical correlation) regression fit, whereas the alternate equations require fewer input variables at the expense of a small loss in fit. Another type of default is provided to supplement data normally supplied by the user primarily in the area of maintenance support costs and factors. The default values in these cases are generally taken from government standards or from published literature. A detailed discussion of all default options is provided in Section 4.1.1.

Table 1.2-1. LCC Model CER's

LCC Phase	CER	Description
RDT&E	RCER	Total development cost (RDT&E) of new custom/semicustom devices.
PRODUCTION	$PCER_1$	Procurement cost of total MC device population (i.e., used in all systems being acquired under a program procurement).
	$PCER_2$	Total screening cost for upgrading desired MC types to higher quality grades.
	$PCER_3$	Total card assembly cost (excluding $PCER_2$) of all cards effected by the MC devices under consideration.
	$PCER_4$	The total cost incurred by cards going through card test and system test. This CER includes a test-rework cycle based on card yields at card-level and system-level testing.
MAINTENANCE AND SUPPORT (M&S)	$MCER_1$	Initial and replenishment spares cost. Initial spares includes site and pipeline stockage. Replenishment spares are based on lifetime losses due to condemnation, pipeline "leakages" etc.
	$MCER_2$	Support equipment cost consists of the development cost for test software and card adapters for fault isolation at the circuit card level.
	$MCER_3$	Inventory entry and supply management costs for new MC devices and cards entered into government inventory.
	$MCER_4$	Depot repair labor cost for fault verification and card repair.
	$MCER_5$	Depot repair materials cost for card repair.
	$MCER_6$	Two-way transportation cost for transporting failed (or suspected failed) cards during the repair cycle.

In using the model computer program and CER's in general, there are a number of ground rules and assumptions that should be noted. These are summarized below:

- All cost factors used in developing the CER's are based on FY 1980 dollars. FY 1980 is used as a "base year" from which all cost escalations are taken.

- LCC estimates are provided in constant, escalated and discounted dollars at sell (i.e., general and administrative factors and a nominal fee have been included) to the government. The rates for escalation and discounting are user inputs with a default to 6% and 10%*, respectively.

- Program phase start dates (i.e., RDT&E, Production and M&S) are user inputs with defaults to FY 1980 start for RDT&E and Production with O&S starting in FY 1981. If a start date other than FY 1980 is used, all cost factors (including default values) are escalated to the new base year.

- Program phase schedules are user inputs for RDT&E and Production with default to zero for RDT&E and one (1) year duration for Production. If multiple year phases are input, the total cost for the phase is allocated uniformly. The schedule for the O&S phase is automatically computed for 5, 10 and 15 years.

- Although it is reasonable to extend the ranges of the MC CER variables to values not included in the data base, care should be exercised to select valid combinations (i.e., a normal physical relationship must be retained.) In this sense the CER parameters are not free to vary in an arbitrary way to investigate cause-and-effect relationships.

- The CER's developed in this study are not applicable to hybrid technology. There was not sufficient data to develop statistical relationships or make meaningful comparisons. However, Hughes has conducted an independent study of hybrid fabrication techniques and costs including a model for estimating fabrication costs.[6]

- Finally, the CER's developed in this study are intended for comparative cost analysis as in design tradeoffs rather than absolute estimation. Thus, common costs which are not sensitive (directly or indirectly) to differences in MC characteristics have been neglected.

1.3 GENERAL EFFECTS OF MC CHARACTERISTICS ON LCC

The MC characteristics (or factors) effecting LCC are discussed in Section 2.3. A large number of factors were considered, a reasonable number of which proved to be good predictors of cost in the CER's. MC factors which were not included in

*Per DOD Instruction 7041.3, Economic Analysis of Proposed Department of Defense Investments.

the CER's were omitted for various reasons or combinations thereof. Typically, these were:

- Insufficient data to make statistical inferences.
- Variations in the dependent variables (i.e., cost, labor hours etc.) already explained by other more important MC factors.
- No significant relationship exists between the factor and the dependent variable.

The following paragraphs summarize the general effects of those MC factors which can have a significant impact on system LCC.

Technology – Device Technology (i.e., bipolar, MOS, ECL, ITL etc.) has an obvious effect on the purchase cost of the device. Not surprising, the most significant factors to consider are whether the device is bipolar or MOS. Bipolar devices are more expensive than MOS particularly in the case of memories. Also, whether or not the device uses ECL logic has a significant effect on increasing the purchase cost. At the card level and higher levels of assembly, device technology exhibits no appreciable affect on assembly and test costs.

Function – As a general rule, memory devices are significantly more expensive to purchase than other functions. MOS memory devices, the exception, are generally less expensive than other functions. Cards with RAM devices tend to have more complex associated circuitry (see below) and, therefore, are more expensive to assemble than cards without RAMS. The percent of MC devices that are RAM's can, therefore, be used as a measure of the card assembly cost. Figure 1.4-1 illustrates the general relationship between fraction of RAM devices used, card density and card assembly costs. Using percentage of RAM usage as a measure of card complexity, Figure 1.4-1 shows that cards containing 25 percent RAM's are approximately twice as expensive to assemble as cards that contain no RAM's. Other device functions, such as decoders, counters, line drivers, etc., showed no significant correlation with cost.

Packaging – The only difference that was discernable in device packaging was whether a dual-in-line package (DIP) or flat-package (FP) was used. Hermeticity was a factor but not significant enough for use in any of the CER's. FP devices are more expensive to procure but, except for material costs, do not have any significant effects on card assembly or test costs. Cards using FP devices are probably more expensive (because of hand wiring) than cards using DIP devices; however, there was not sufficient data to test this premise. Hughes primarily uses DIP devices in card assembly or a mix of DIP's and FP's.

Complexity – The number of gates per device had an effect on the cost of device development (RDT&E), device procurement and device screening (for quality upgrade). Figure 1.4-2 gives the development cost per gate for custom LSI devices

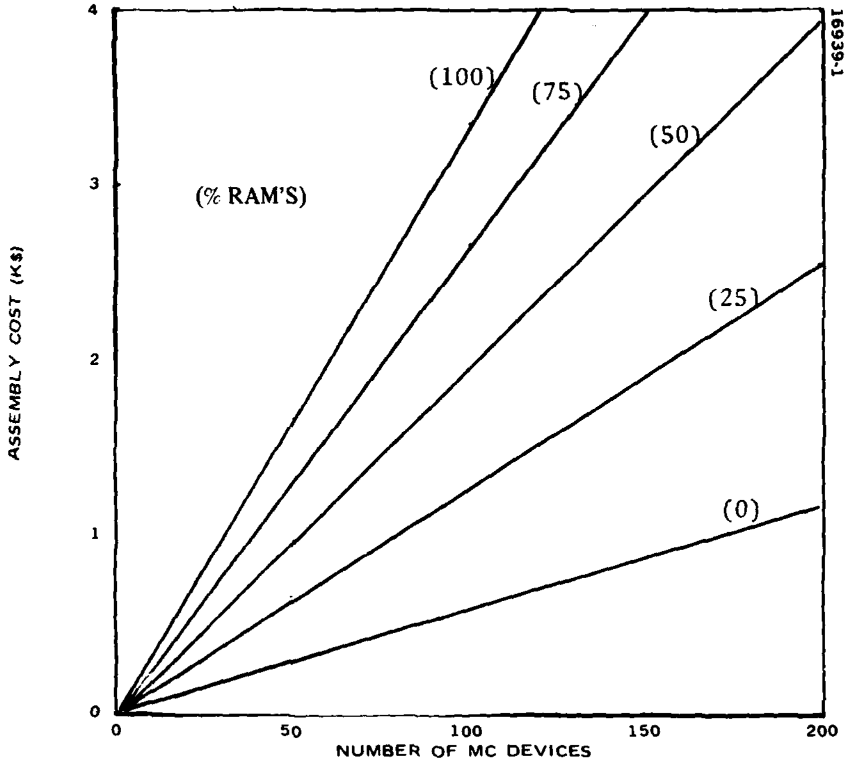

Figure 1.4-1. Card Density vs Assembly Cost

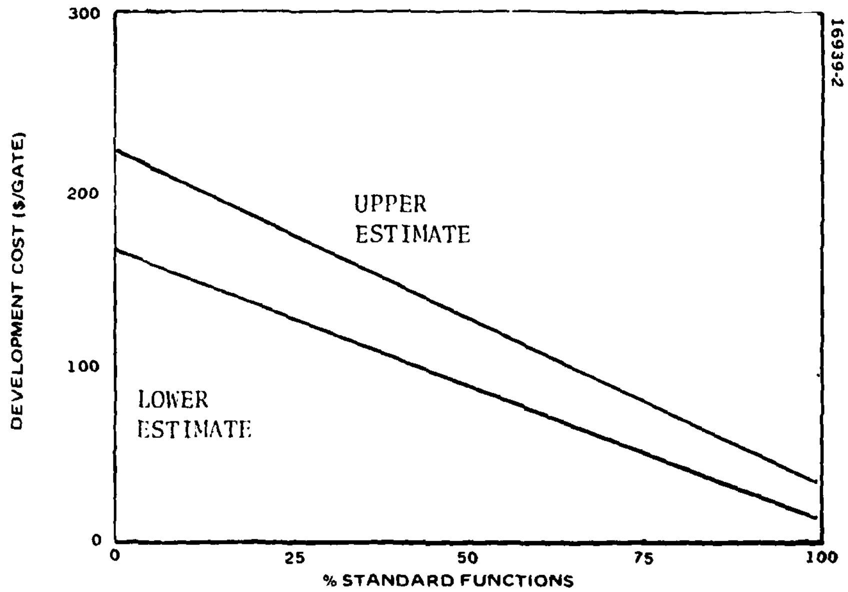

Figure 1.4-2. LSI Development Cost Per Gate

as a function of the fraction of standard (already developed) functions. The upper and lower bounds in the figure are extrapolations from published data. For example, the development cost for a 2000 gate device utilizing 50% standard functions would range from $180K to $250K depending on functional complexity. Differences in the device complexity also has an effect at the card level particularly if the devices are linear. Figure 1.4-3 illustrates the impact of increasing complexity on card test labor for various mixes of linear devices. For a 1K gate card which contains 25% linear devices the test labor is approximately 5.5 hours. This compares to a digital card of the same gate count which requires approximately 2 hours testing.

Quality/Reliability – Device quality grade affects procurement cost when considered on a per gate or per BIT basis. For off-the-shelf available devices, reliability is not a significant factor in cost determination particularly at the higher gate or BIT counts. At the card level, reliability had a very significant effect on the card test-rework cycle. The number of MC devices which are of quality grade B-2 or lower has significant correlation with test yield. Figure 1.4-4 gives the fractional yield at card test as a function of fraction MC devices with quality grade B-2 or lower using a 100-device card. A 75% MC device usage is assumed on the card. The figure shows that as the number of linear MC devices increases, the yield at card test becomes lower.

Other MC Factors – Card density (i.e., quantity of devices per card) has an effect on higher assembly test yield which becomes more significant as the usage of MC devices increases (see Figure 1.4-5). For example, cards that contain 100 devices all of which are MC's will have an assembly test yield of approximately 83 percent.

When a change in device family results in a re-partitioning of the system (eg, from SSI/MSI devices to LSI devices), government inventory, spares and lifetime maintenance costs can be effected. Figure 1.4-6 illustrates the impact of introducing new items (devices, cards, etc.) into government inventory and maintaining these items for 15 years. These costs are also a function of the number of base supply systems involved in which card inventories must be maintained (see Section 3.3.4). If, for example, 30 new device types are inventoried the 15 year maintenance cost would be approximately $60K. If, 10 new card types are also inventoried at 5 base supply systems, an additional cost of $50K would be incurred for a total cost of $110K.

The effect of a change in device family on sparing, support equipment and depot maintenance is dependent on a large number of system-level and logistic support considerations. These effects are best illustrated by examples using the LCC model (see Section 4.2).

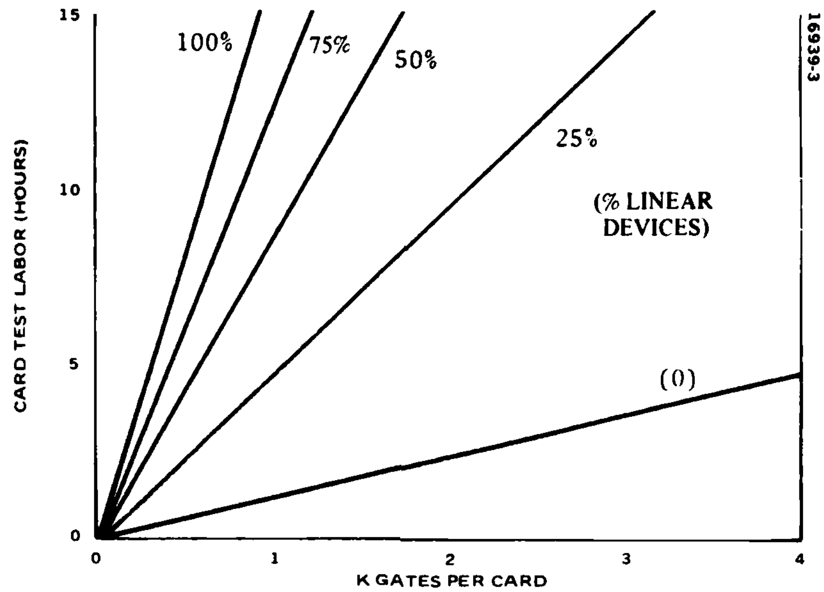

Figure 1.4-3. Card Complexity vs Card Test Labor

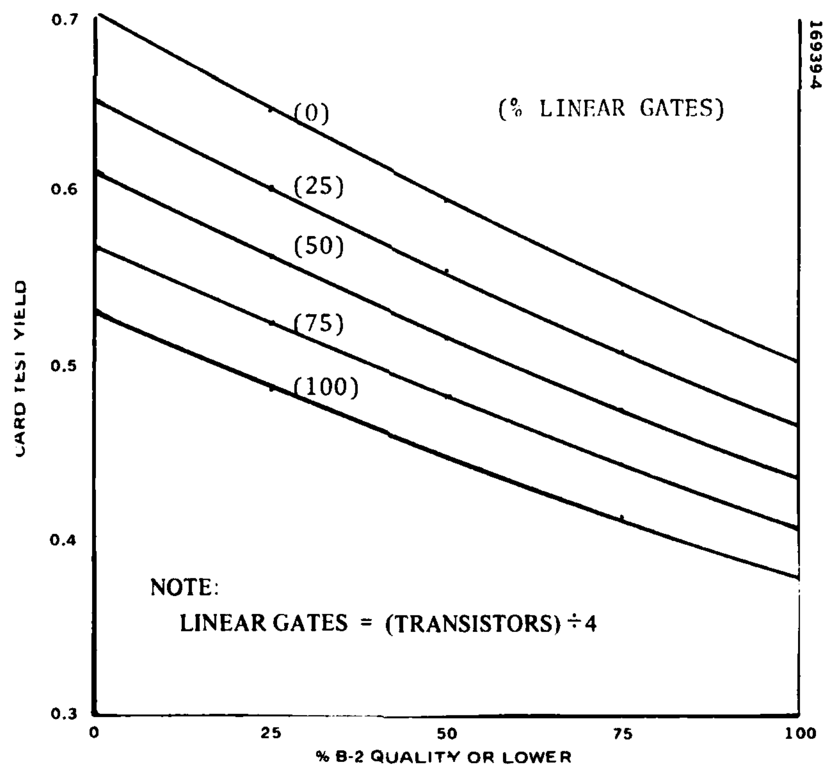

Figure 1.4-4. Device Quality vs Card Test Yield (100 Devices Per Card with 75% MC)

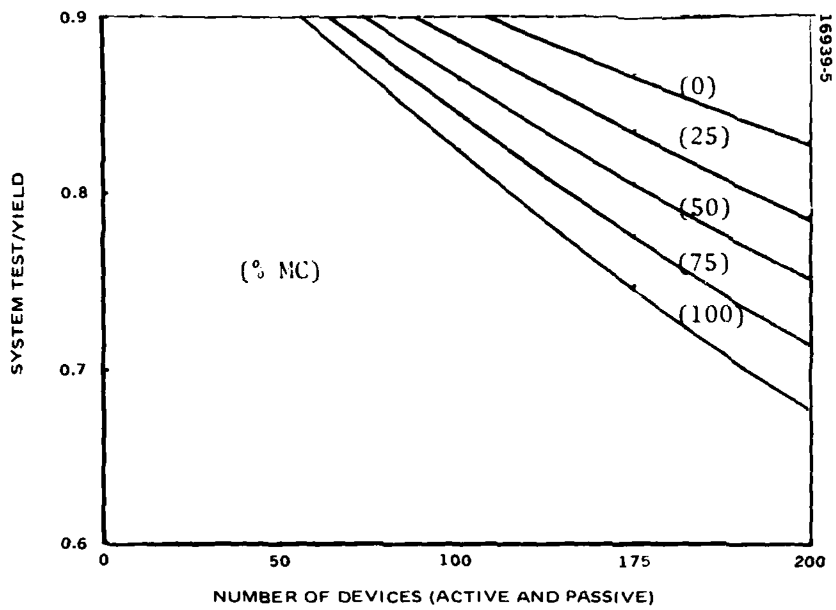

Figure 1.4-5. Card Density vs System Test Yield

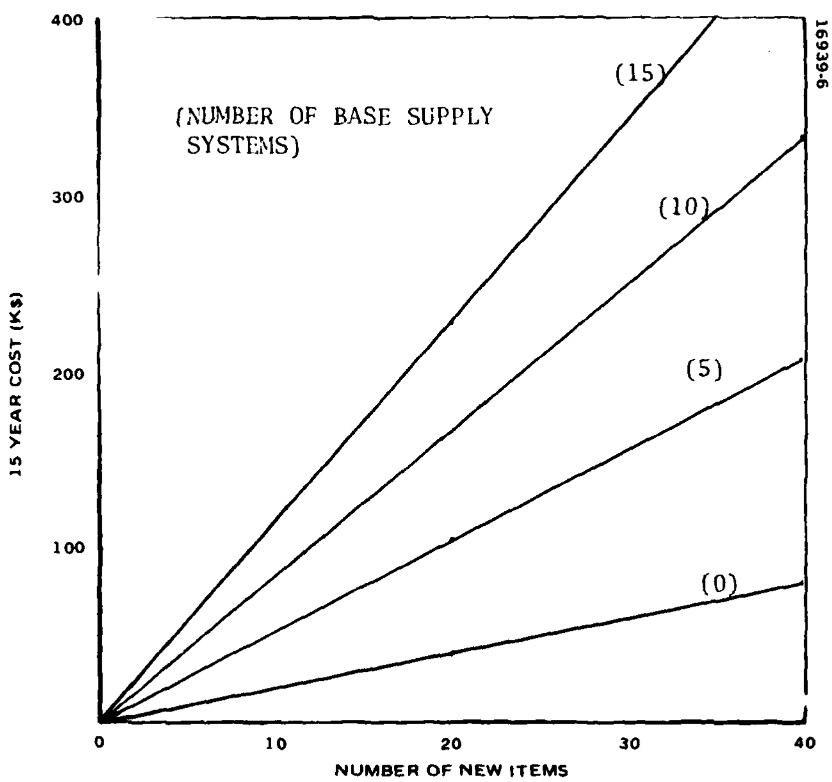

Figure 1.4-6. Inventory Entry and Supply Management Cost

Section 2.0

DATA BASE DESCRIPTION

2.1 SOURCES OF DATA

In order to provide a statistically significant data base for the prediction model, fifteen systems/product lines in current manufacture at Hughes were surveyed.

From the surveyed systems, seven were selected to provide the study data base. The criteria for selection of the seven systems were:

a) Systems selected must represent a variety of equipment types.

b) Formal reliability analysis and prediction per MIL-HDBK-217C must have been completed on the system.

c) The systems must be of recent vintage (i.e., post 1970), employing current state-of-the-art MC technology.

d) Data collected on the systems must be relatable to MC cost factors considered in this study.

The product lines and card types used in the data base are given in Table 2.1-1. Within each product line a wide variety of card types were selected to enhance the range of applications for the MC parameters under consideration. For each product line, data was collected according to four sources: Plant, Program, Card and Device. The MC characteristics for which data was collected from these sources is summarized in Section 2.3.

Plant or factory level data could not be allocated to specific cards (i.e., by assembly number) or programs but did provide measures of the combined trend of the selected systems. Such data was used only when obtaining lower level data was impractical or statistically meaningless. Plant level sources of data include labor logs on card-rework (exclusive of fault isolation and checkout testing labor which was accessible at the card level), system test (i.e., labor required to fault isolate to the card level), and device reliability upgrade data.

Table 2.1-1. Systems and Card Configurations Used in Data Base

Production Line	Card Function	Type	Percent MC Devices
Micro-Computer	Memory Interface	Digital	44
	Arithmetic Register	Digital	52
	External Register Control	Digital	51
	Serial Channel Interface	Digital	45
	Memory (ROM)	Digital	31
	Power Fault Determinator	Mix, Digital/ Linear	34
	BITE Power Supply	Linear	9
Display Console	Refresh Memory	Digital	32
	Sweep Generator	Mix, Digital/ Linear	65
	Line Generator	Mix, Digital/ Linear	14
General Purpose Computer	Memory Control Timing	Digital	48
	Electrical Memory Card	Digital	33
	Memory Input Switch	Digital	54
	Effective Address Logic	Digital	37
	16 BIT Microprocessor	Digital	49
Communications Terminal	Memory Interface	Digital	55
	Indicator Logic	Digital	37
	Correlator Preamble	Mix, Digital/ Linear	15
Submarine Fire Control System	Test Sensor/Focus Programmer	Linear	6
	Clock Generator	Linear	15
	Counter Digital Rate Multiplier	Linear	77

Table 2.1-1. Systems and Card Configurations Used in Data Base (Continued)

Production Line	Card Function	Type	Percent MC Devices
Submarine Fire Control System (Continued)	Deflection Counter/Monobit Encoder	Digital	80
	Pincushion Correction	Linear	5
	Data Select	Digital	67
	Test Logic	Digital	65
	Display Control A	Digital	79
	Display Control B	Digital	74
	Display Control C	Digital	81
	Edit Control Generator	Digital	69
	Symbol Integrator/Reference Supply	Linear	72
	Stroke Control	Digital	81
	ROM A	Digital	41
	ROM B	Digital	39
	ROM C	Digital	37
	Symbol Address	Digital	78
	Intensity Compensation and Gating	Linear	1
	Digital Logic	Digital	69
	Panel Interface	Digital	79
	Test Logic Sensor	Linear	2
Mortar Locating Radar	Integrated clutter map	Mix, Digital/ Linear	55
	Modulated Frequency Shift	Linear	14
	Easting Driver	Digital	36
	Microprocessor Controller	Digital	37
	External Control Register	Digital	50

Table 2.1-1. Systems and Card Configuration Used in Data Base (Continued)

Production Line	Card Function	Type	Percent MC Devices
Mortar Locating Radar (Continued)	Diagnostic Interface	Digital	40
	Doppler Filter	Linear	60
	4K RAM	Digital	34
	MLVL Signal Generator	Linear	53
	ROM Circuit	Digital	46
	Gate	Digital	45
	Data Path Communication	Digital	51
	Dual Channel Control	Digital	49
Artillery Locating Radar	RAM	Digital	51
	Analog-Digital Convertor	Mix, Digital/ Linear	6
	Signal Generator	Linear	52
	Microsequencer	Digital	49
	Synchronizer	Digital	47
	Target/Bite	Digital	50
	Dual Channel Control	Digital	30
	Clock Oscillator	Linear	32
	Multiplexer	Digital	40
	Gate	Digital	67
	Canceller	Digital	59

Program level data could be allocated to a specific program but not to specific cards. Program level data were gathered on this level only when lower level data were inaccessible or statistically meaningless. Sources of program level data include card defect analysis reports for specific product lines.

Card level data consisted of specific cards (by assembly number) with known MC characteristics. Such data had the highest priority during the data collection effort. Sources of card level data consisted of card assembly cost reports, quality control defect analysis reports, system test defect analysis reports and configuration parts lists used in reliability and maintainability predictions.

Device level procurement data account for specific MC device types and was collected from purchase price lists. Data on research, development, test and evaluation (RDT&E) for custom and semi-custom LSI devices was obtained from internal pricing guides and from data in the literature survey (see 3.1.1).

Section 3 contains a detailed description of the data used for each CER. Sources for cost data and factors applicable to the support phase of the life cycle were provided by Government standards. Table 2.1-2 summarizes the sources of data used for developing the MC CER's. The references indicated provide a detailed discussion of MC parameters used and CER development.

2.2 DATA PROCESSING METHODOLOGY

In order to determine which MC parameters had a significant effect on various system costs and to provide accurate CERs, a multiple linear regression technique was employed. The basic assumptions of this technique are:

1) The dependent variable Y (cost, labor hours, etc.) is a linear combination of p independent variables (MC characteristics, card characteristics, etc.) This relation is called a regression equation, and in matrix notation the model may be represented in the form:

$$Y = XB + e \tag{2-1}$$

where

Y is a (nX1) vector of observations of the dependent variable.

X is a (nXp) matrix of observations of the independent variables.

B is a (pX1) vector of parameters (CER coefficients) to be estimated.

e is a (nX1) vector of errors

2) The elements e_i $1 \leq i \leq n$ of the vector e represent values of a normally distributed random variable. This assumption is reasonable since the error term is most probably the sum of errors from a large number of sources and, therefore, by the Central Limit Theorem their sum will have a distribution that will be approximately normal regardless of the type of probability distribution the separate error components may have.

Table 2.1-2. Summary of Data Sources for CER's

Cost Estimating Relationship		Data Source	Section Reference
Description	Code		
RDT&E for Custom IC's	RCER	Literature Search, Plant Level	3.1.2
Device Procurement	$PC\ ER_1$	Device Level	3.2.2
Device Screening	$PC\ ER_2$	Device Level	3.2.3
Card Assembly	$PC\ ER_3$	Device Level, Card Level	3.2.4
Card-Test-Rework Cycle:	$PC\ ER_4$		
• Card Test Labor	H	Device Level, Card Level, Program Level	3.2.5.1
• Card Test Yield	YC	Device Level, Card Level, Program Level	3.2.5.2
• System Test Yield	YS	Device Level, Card Level, Program Level	3.2.5.4
• System Repair	C2	Plant Level	3.2.5.5
• Card Rework	C3	Program Level, Plant Level	3.2.5.3
Spares	$MC\ ER_1$	Card Level, Government Standards	3.3.2
Support Equipment	$MC\ ER_2$	Plant Level	3.3.3
Inventory Entry and Supply Management	$MC\ ER_3$	Government Standards	3.3.4
Repair Labor	$MC\ ER_4$	Card Level, Government Standards	3.3.5
Repair Materials	$MC\ ER_5$	Government Standards	3.3.6
Maintenance Transportation	$MC\ ER_6$	Government Standards	3.3.7

3) $E(e) = 0$, $V(e) = I\sigma^2$, where I is the identity matrix, so the elements of e are uncorrelated. That is, $E(Y) = XB$. The error sum of squares for the system is:

$$
\begin{aligned}
e'e &= (Y - XB)'(Y - XB) \\
&= Y'Y - 2B'X'Y + B'X'XB
\end{aligned}
$$

By differentiating this equation with respect to B and setting the resulting equation to zero and replacing B by b, the normal equations result:

$$
\begin{aligned}
(X'X)b &= X'Y \\
b &= (X'X)^{-1} X'Y
\end{aligned}
\tag{2.2}
$$

This solution b, called the least squares estimate of B, has the property of being the best linear, unbiased, estimate. Further details are given in Draper and Smith.[1]

Multi-linear regression analysis is expedited by using the UCLA Health Sciences Bio-Medical multi-linear regression computer program (BMD02R).[2] This regression analysis computes a sequence of multiple linear equations in a step-wise manner. The procedure moves step by step from one regression to the next, adding a predictor (forward regression) or deleting a predictor (backward regression) at each step. This produces a sequence of regression functions:

$$
\begin{aligned}
y &= b_o + b_1 x \\
y &= b'_o + b'_1 x_1 + b'_2 x_2 \\
y &= b''_o + b''_1 x_1 + \ldots + b''_p x_p
\end{aligned}
\tag{2.3}
$$

Rather than adding predictors in order, the program steers the additions/deletions by three statistical tests:

- The F-to-enter statistic for a predictor is the F-statistic for testing the significance of the regression coefficient the predictor would have if it were added. (A predictor will not be entered if its F-to-enter value is below a specified threshold.)
- The F-to-remove statistic of an entered predictor is simply the value of the F-statistic used to test the significance of its regression coefficient. (If its F-to-remove value is less than a specified threshold, a predictor will be removed.)
- The tolerance of a non-entered predictor is one minus the square of the multiple correlation between this predictor and those predictors currently in the regression function. (The tolerance threshold is used to prevent the entry of highly correlated predictors and to avoid rounding error in the computations.)

Three rules control step operation:

1) If there are one or more predictors in the regression equation whose F value is less than the F-to-remove value specified, the one with the smallest F value will be removed.

2) If no predictor is removed by (1) and there are one or more independent variables not in the regression equation which pass the tolerance test, the one with the highest F value will be entered.

3) If no predictor is added or removed by (1) or (2) the stepwise procedure stops.

The ratio:

$$R^2 = \frac{\Sigma(\hat{Y} - E(Y))^2}{\Sigma(Y - E(Y))^2} \tag{2.4}$$

is the square of the multiple correlation coefficient and is a measure of the usefulness of the predictors in the CER model. R^2 measures the percent variation explained by the model. Thus, if the estimated values of the CER ($\hat{Y}_i$) equals the observed values (Y_i) for all $1 \le i \le N$ (i.e., if the prediction is perfect), then $R^2 = 1$. If $b_1 = b_2 = \ldots = b_p = 0$ (or a model $Y = B_o + e$ alone has been fitted), then $R^2 = 0$.

In developing a useful CER for a particular cost area, several of the equations (2.3) may be of value. Each successive step provides an equation which explains more of the variation (higher R^2) but also requires more independent variables for which the user must provide data. Thus, a selection of prediction equations with differing input requirements have been provided for most of the CER's developed from regressions. Section 3 provides a detailed description of the basic CER used in the LCC model and applicable alternate CER's.

2.3 MC FACTORS EFFECTING COST

In formulating the model CER's as many MC factors were considered as could be accommodated by the regression limits and data. Although many candidate cost predictors were considered during the study, only those found to be both physically meaningful and statistically significant were incorporated in each CER.

Table 2.3-1 provides a list of all MC factors (independent variables) which were considered to possibly have some influence on cost (dependent variable). Those MC factors that had significant impacts on cost are identified by an "X". The corresponding CER's in which they are employed are also given. These factors effect the various aspects of system cost directly through device development, procurement and/or testing, and also, indirectly, through their impact on card assembly, test and lifetime support. For example, device quality effects the cost of device procurement but also has an even greater impact on the card production cost through the card test yield. Similarly, since the cost per card

Table 2.3-1. MC Factors Effecting LCC

MC Factors: Description	Applicable to CER	Variable	Applicable CER's
Technology:			
Linear	X	1-DIG	Device Purchase ($PCER_1$ 3.2.2)
Bipolar	X	1-MOS	Device Purchase ($PCER_1$ 3.2.2)
ECL	X	ECL	Device Purchase ($PCER_1$ 3.2.2)
MOS (PMOS, NMOS & CMOS)	X	MOS	Device Purchase ($PCER_1$ 3.2.2)
Digital	X	DIG	Device Purchase ($PCER_1$ 3.2.2)
Bipolar	X	1-MOS	Device Purchase ($PCER_1$ 3.2.2)
DTL			
TTL			
ECL	X	ECL	Device Purchase ($PCER_1$ 3.2.2)
IIL			
MOS (PMOS, NMOS & CMOS)	X	MOS	Device Purchase ($PCER_1$ 3.2.2)
Schottky			
Low-power Schottky			
Low-Power			
High Speed			
Function:			
Memory	X	MEM	Device Purchase ($PCER_1$ 3.2.2), Device Screen ($PCER_2$ 3.2.3)
RAM(QTY on Card)	X	NRAM	Card Assembly ($PCER_3$ 3.2.4)
ROM			
PROM			
EPROM			
Decoders			
Counters			
Flip-Flops			
Dividers			
Line Drivers			
Packaging:			
DIP	X	1-FP	Device Purchase ($PCER_1$ 3.2.2)
Flatpack	X	FP	Device Purchase ($PCER_1$ 3.2.2)
Leadless			
Single Chip			
Beam Lead			
Hermetically Sealed			
Complexity:			
Gates (Qty on Device)	X	NG	RDT&E (RCER 3.1.2), Device Purchase Screen ($PCER_2$ 3.2.3)
Digital (Qty on Card)	X	NDG	Card Test Hours (H 3.2.5), Repair Labor ($MCER_4$ 3.3.5)
Linear (4-trans = 1 Gate; Qty on Card)	X	NLG	Card Test Hours (H 3.2.5), Card Test Yield (YC 3.2.5), Repair Labor ($MCER_4$ 3.3.5)
Pins (Qty on Device)	X	NP	Device Screen ($PCER_2$ 3.2.3)
BITS (Qty on Device)	X	NB	Device Purchase ($PCER_1$ 3.2.2), Device Screen ($PCER_2$ 3.2.3)

Table 2.3-1. MC Factors Effecting LCC (Continued)

MC Factors			
Description	Applicable to CER	Variable	Applicable CER's
Quality/Reliability:			
Quality Grade S B B-1 B-2 and Below	X	QB2	Card Test Yield (YC 3.2.5)
Reliability (Weighted/MIL-STD-217C)	X	REL	Device Purchase ($PCER_1$ 3.2.2)
Combined MC Characteristics:			
TTL, DTL			
Linear, Beam Lead, ECL			
MOS (Linear or Digital)	X	MOS	Device Purchase ($PCER_1$ 3.2.2), Device Screen ($PCER_2$ 3.2.3)
Digital Bipolar SSI/MSI, Digital MOS SSI/MSI			
Digital Bipolar LSI, Digital MOS LSI			
ECL (Linear or Digital)	X	ECL	Device Purchase ($PCER_1$ 3.2.2)
IIL, Low-power TTL			
MOS Memory, Bipolar Memory			
AVG. Quality Grade/MIL-STD-217C			
Other Considerations:			
MC Devices (Qty on Card)	X	NMC	Card Test Hours (H 3.2.5), Card Test Yield (YC 3.2.5), System Test Yield (YS 3.2.5)
Devices Active and Passive: (Qty on Card)	X	NDEV	Card Assembly ($PCER_3$ 3.2.4), Card Test Hours (H 3.2.5), Card Test Yield (YC 3.2.5), System Test Yield (YS 3.2.5)
Ratio Contri. of MCs to the Card Failure Rate	X	W	Card Test Hours (H 3.2.5), Card Test Yield (YC 3.2.5), Spares ($MCER_1$ 3.3.2), Repair Labor ($MCER_4$ 3.3.5), Repair Materials ($MCER_5$ 3.3.6), Main. Trans. ($MCER_6$ 3.3.7)
Card Failure Rate	X	CF	Spares ($MCER_1$ 3.3.2), Repair Labor ($MCER_4$ 3.3.5), Repair Materials ($MCER_5$ 3.3.6), Main. Trans. ($MCER_6$ 3.3.7)

and card reliability are effected by device quality so is the cost of spares and maintenance support.

The effects of the MC characteristics on individual CER's are discussed in the appropriate subsections of Section 3.

Section 3.0

DESCRIPTION OF MODEL COST FACTORS

3.1 MC RESEARCH, DESIGN, TEST & EVALUATION (RDT&E)

3.1.1 LITERATURE SEARCH

In order to compare internal cost experience in custom/semi-custom LSI development, a literature search was conducted. The search was restricted to only recent publications going back three years. The data banks included in this search were DOD Documentation Center (DDC), National Technical Information Service (NTIS) the NASA Data Bank, and the Lockheed Dialog Information Retrieval Service. All journals, reports and general technical information on RDT&E costs associated with custom/semi-custom LSI devices were included.

There is a tremendous amount of literature on LSI devices. However, there seems to be a great reluctance to publish RDT&E cost data. Of the items listed in the searches only seventeen required closer review, and of these only three provided any useful information on RDT&E costs. These items are given in the bibliography. Of particular interest to this study is a comprehensive report on the application of LSI technology to military systems including an analysis of LCC.[2] This report was used to compare the various aspects of costs and trends in technology.

3.1.2 RDT&E (RCER)

The cost to develop an LSI device varies considerably depending on the complexity and the degree to which the device design can utilize standard already-developed functions. When standard gate arrays are employed the development cost per gate can be competitively low because the development of final metallization layers is all that remains, thus minimizing the design layout errors which reduces design, test and evaluation costs considerably. Completely custom LSI's are not cost competitive unless large quantities are procured or developed through functional standardization. How large the procurement must be is subject to tradeoff. As logic designs become more complex, the applications become more unique and, therefore, more costly to develop on a per device basis. On the other hand, microprocessors were developed as a method supplying a sufficiently large number of random logic functions to warrant their economical development. Therefore, functional standardization in LSI is

achievable through the microprocessor, and this appears to be the trend in the future in military electronics.[5,8]

At the low cost end (i.e., using standard functions), the cost to develop an LSI device starting with the logic design can vary from $12 to $30 per gate (1977 dollars). At the high cost end, the cost can vary from $150 to $200 per gate (1977 dollars)[4,7] If these cost extremes are averaged and brought up to current 1980 dollars*, we can expect a variation of from $24 per gate to $203 per gate. Thus, for a 2000 gate device, the RDT&E cost in today's dollars would be:

	K$
• Complete Custom	406
• Standard Functions	48

These values are in fairly good agreement with Hughes experience in estimating RDT&E for LSI devices.

The CER for RDT&E is based on the average cost per gate assuming a linear relationship between cost per gate and fraction of standard functions employed. Thus, the total RDT&E for N device types is given by:

$$\text{RCER} = \sum_{i=1}^{N} NG(i)\left[\left(C_{MIN} - C_{MAX}\right)F(i)_{STD} + C_{MAX}\right] \quad (3.1)$$

where:

$NG(i)$ = Total gate count of i^{th} device type.

C_{MIN} = Cost per gate using standard functions ($24)

C_{MAX} = Cost per gate for complete custom device ($203)

$F(i)_{STD}$ = Fraction made from standard functions, i^{th} device type.

Since there are large variances in the cost per gate in (3.1) based on the LSI manufacturer's unique design process, the values of C_{MIN} and C_{MAX} are user inputs in the LCC model. The values given above are provided as defaults when the user has no better information.

The development cost of custom LSI's can also be off-set to some degree by reducing the number of items to be inventoried, documented and spared, and by simplifying system design (e.g., less complex back-plane wiring). In any event, the total cost picture needs to be examined before a clear economic decision can be made.

*A compound rate of 5% is used. Although this rate is low with respect to the inflation of the past few years, it has been off-set by advances in the LSI development technology which have tended to reduce costs.

3.2 PRODUCTION INVESTMENT

3.2.1 MANUFACTURING MODEL

Figure 3.2.1-1 illustrates the flow of MC devices through the manufacturing process. Starting with device procurement ($PCER_1$) the devices are (possibly) screened to a higher reliability grade ($PCER_2$) and mounted on circuit boards ($PCER_3$). The circuit board (cards) are then tested at the card-level and system level ($PCER_4$) before final acceptance of the "host" system by the contracting agency. During card-level and system testing, MC device failures occur which cause the card to go through a rework-retest cycle indicated by the "feed-back" loops in the figure. Failures other than MC devices, of course, will also occur but we are only considering the impact on LCC of MC device failures. Once the devices have been mounted on cards, it is at this step in the process that the card and, therefore, the devices start accumulating "hidden" costs.

As a quantity of cards of a particular type (i.e., a unique function) is processed through Card Test and System Test (i.e., all higher assembly testing) a portion of these cards fail card test and a portion pass on to the system level. Similarly, at the system level a portion will fail and a portion will become part of the system. Those cards failing at either test are sent to rework after which they must repeat the process at the card and system level. Thus, with yields of Y_c at the card-level and Y_s at the system level, the cumulative effects on the card cost can be computed.

The probability that a card fails card test and is sent to rework is (1-Yc) and the probability that a card passes card test and fails system test is Yc(1-Ys). Thus, the probability that a card is sent to rework, either from the card level or system level is simply: $(1-Y_c) + Y_c(1-Y_s) = 1-Y_cY_s$.

Clearly, the number of cards entering the process at the n^{th} cycle (X_n) is equal to the number of failures of those processed on the previous cycle (X_{n-1}) and so forth, i.e.:

$$X_n = X_{n-1}(1-Y_cY_s) = X_{n-2}(1-Y_cY_s)^2 = \cdots = X_1(1-Y_cY_s)^{n-1} \tag{3.2}$$

If C_1, C_2 and C_3 are the card test cost, system test cost and rework cost, respectively, the total cost of processing X_n cards is:

$$X_nC_1 + X_nY_cC_2 + X_n(1-Y_cY_s)C_3$$

or, $$X_n\left[C_1+C_2Y_c+C_3(1-Y_cY_s)\right]$$

or, $$X_1(1-Y_cY_s)^{n-1}\left[C_1+C_2Y_c+C_3(1-Y_cY_s)\right]$$

Hughes' manufacturing experience indicates that it is rare for cards to be scrapped as a result of cumulative damage incurred during the rework process. Therefore, as a good approximation, the process can be summed up as an infinite geometric series:

$$\sum_{n=1}^{\infty} X_1\left[C_1+C_2Y_c+C_3(1-Y_cY_s)\right](1-Y_cY_s)^{n-1} = X_1\left[C_1+C_2Y_c+C_3(1-Y_cY_s)\right]/(Y_cY_s)$$

16174-1

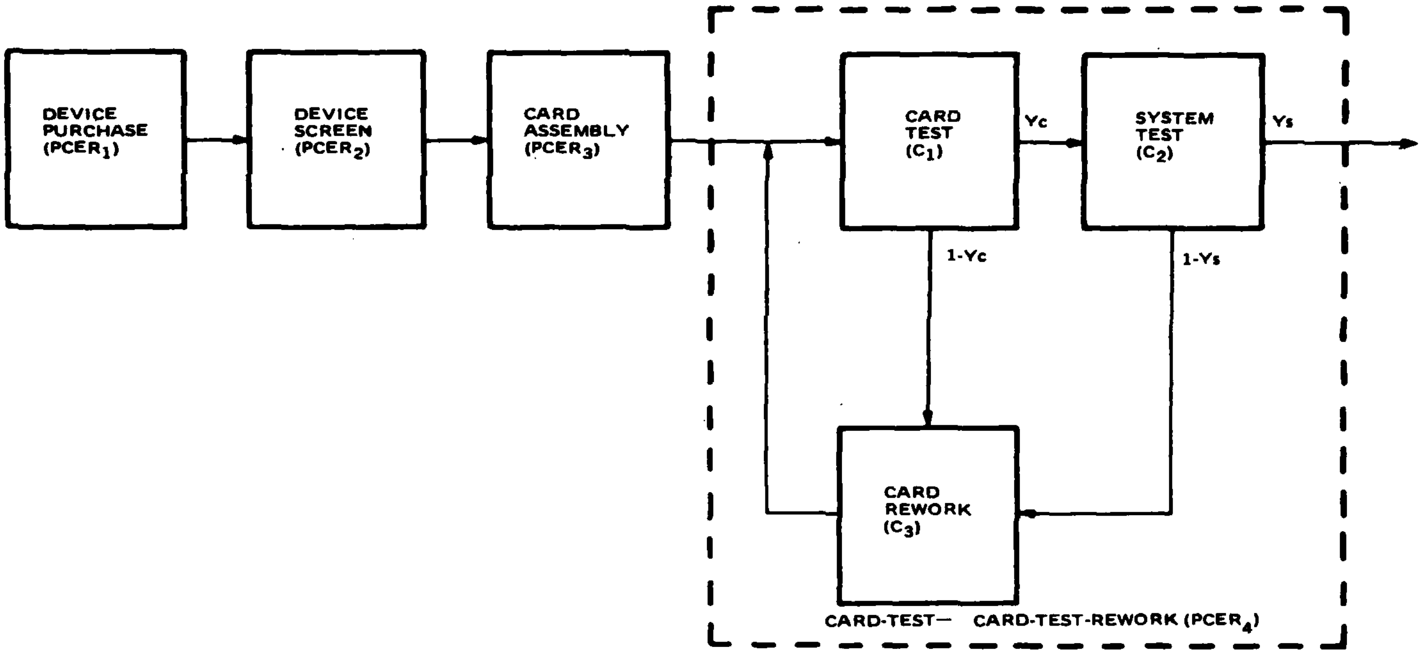

Figure 3.2.1-1. Manufacturing Process Model

where

$$0 < 1 - Y_c Y_s < 1$$

If X_1 represents all the cards required by the production program, then:

$$\text{(3.3)} \quad PCER_4 = X_1 \left[C_1 + C_2 Y_c + C_3 (1 - Y_c Y_s) \right] / Y_c Y_s$$

The total production cost (C_{PROD}) with appropriate summation across device types (N) and card types (N_c) is therefore given by:

$$\text{(3.4)} \quad C_{PROD} = \sum_{i=1}^{N} \left[PCER_1(i) + PCER_2(i) \right] DEVQ(i) + \sum_{i=1}^{N_c} \left[PCER_3(i) + PCER_4(i) \right] CARD(i)$$

Formulated CER's have been developed to predict each area of the manufacturing process which is sensitive to differences (either directly or indirectly) in MC characteristics. The details of these developments are provided in Sections 3.2.2 through 3.2.5. The effects of other costs (i.e., device supplier qualification costs, device obsolescence, on-shore versus off-shore procurements, etc.) are discussed in Section 3.4. In the following sections the subscript denoting the i^{th} device or card type will be dropped.

3.2.2 DEVICE PROCUREMENT ($PCER_1$)

Data was collected from two main sources:

- HAC Vendor Integrated Circuits Pricing Agreement
- Linear, Digital, Memory and Interface Integrated Circuits D.A.T.A. Books of the Electronic Information Series

For each MC device according to device number, the Integrated Circuits Pricing Agreement enabled the determination of device technology, packaging (Dual inline package, flat package, etc.) reliability grade, whether or not the device was hermetically sealed and unit cost. The D.A.T.A. books then provided information on the device type and function, number of gates, and number of bits for memory devices. The reliability grades were assigned weightings according to MIL-STD-217.

Table 3.2.2-1 identifies the MC device characteristics that provided significant correlations with purchase cost. Sixty nine data points were used to test nineteen MC characteristics using the stepwise regression procedure. Table 3.2.2-2 provides the applicable CER's for estimating the unit cost of an MC device with given characteristics. The complete regression runs are given in Appendix A-2.

TABLE 3.2.2-1 DEVICE PROCUREMENT VARIABLE DESCRIPTION

VARIABLE	DESCRIPTION	UNITS	RANGE
$PCER_i$	PROCUREMENT COST PER DEVICE	$	0.24 - 30.79
MEM	MEMORY DEVICE	Indicator[1]	0,1
DIG	DIGITAL LOGIC DEVICE	Indicator	0,1
ECL	ECL DEVICE	Indicator	0,1
MOS	MOS DEVICE	Indicator	0,1
FP	FLATPACK DEVICE	Indicator	0,1
REL	RELIABILITY	(2)	0.0 - 35.
GATES	NUMBER OF GATES	QTY	0 - 68
BITS	NUMBER OF BITS	QTY	0 - 16384

[1] The indicator has value "1" if the characteristic is present, "0" otherwise.

[2] The following weightings were employed for the given quality grades:

QUALITY GRADE	S	B	B-1	B-2	C	C-1	D	D-1
RELIABILITY FACTOR	0.5	1.0	3.0	6.5	8.0	13.0	17.5	35.0

Using the coefficients (C's) in the table, the basic CER is:

(3.5) $$PCER_1 = EXP\,(.52165+1.38197\cdot MEM-.69142\cdot DIG+1.84202\cdot ECL$$
$$-2.70211\cdot MOS+.56445\cdot FP-.22443\cdot (REL/GATES)$$
$$-9.83248\cdot (REL/BITS))$$

The alternate CER's given in the table can be written in a similar manner, The indicator variable MEM was found to explain most of the variation (approximately 30%) in device cost.

It should be noted that the cost computed by PCERI is for off-the-shelf devices in large quantity procurements. For a new device (eg, a custom LSI), a learning curve should be applied to the CER as follows (see Section 3.4.1 for a discussion of learning curve applications):

(3.6) $$PCER'_1(X) = AX^{\alpha}$$

TABLE 3.2.2-2 CER's FOR DEVICE PROCUREMENT

CER	CONSTANT	INDEPENDENT VARIABLE							R	VARIABLES REMOVED
		MEM	DIG	ECL	MOS	FP	(REL/ GATES)	(REL/ BITS)		
	C1	C2	C3	C4	C5	C6	C7	C8		
BASIC	.52165	1.38197	-.69142	1.84202	-2.70211	.56445	-.22443	-9.83248	.85	-----------
1	.02207	1.84461	-------	1.58816	-2.66517	.60918	-.20841	-9.15497	.84	DIG
2	.29528	1.90967	-------	1.66451	-3.00344	------	-.23836	-11.35440	.80	DIG, FP
3	.29312	1.69924	-------	1.66570	--------	------	-.23799	-9.29049	.76	DIG, FP, MOS

$$PCER_1 = EXP\,(C1 + C2 \cdot MEM + C3 \cdot DIG + C4 \cdot ECL + C5 \cdot MOS + C6 \cdot FP + C7 \cdot (REL/_{GATES}) + C8 \cdot (_{REL/}BITS)$$

where:

$PCER'_1(X)$ = Adjusted unit cost for a procurement of X devices.

A = Adjustment factor for converting off-the-shelf unit cost ($PCER_1$) to the theoretical first unit cost

X = Procurement quantity

α = Learning slope factor

3.2.3 DEVICE SCREENING ($PCER_2$)

Data for the Device Screening CER was assembled based on Hughes internal device screening procedures per MIL-STD-883B, Method 5004.4 and MIL-M-38510D for general purpose microelectronic devices. Manpower, labor grades and material costs to perform the screening procedures were considered with respect to the general level of complexity of MC devices. In addition, memory devices are more expensive to test than non-memory devices, primarily because of the extra time spent in electrical test and the burn-in material costs. The average labor hours and costs given in Table 3.2.3-1 were allocated on a per-device basis, although actual estimating was achieved on a lot sizes of 50 - 100 devices.

For interim and final electrical testing, it is assumed that an automatic tester is used. The figures in the table represent labor required using a Sentry Tester. If bench testing is used, however, the labor required could be 3 to 4 times that shown in the table.

It should be noted that when device screening is employed, 100% testing is assumed. Also, destructive physical analysis per MIL-STD-38510D which is sometimes performed on a sampling basis is not included in the CERs since this is an insignificant cost for reasonable procurement quantities.

The resulting quality grade of screened MC devices is B-1. If a device is new, additional Engineering labor hours (non-recurring) is incurred to set up the computer programming for the Sentry Tester as a function of device complexity:

- SSI/MSI Non-Memory Devices - - - - - - - 20 Hours
- SSI/MSI Memory Devices - - - - - - - - - - 80 Hours
- LSI Devices - - - - - - - - - - - - - - - - - 180 Hours

The CER data for device screening is summarized in Table 3.2.3-2. The general form of the Device Screening CER is:

$$PCER_2 = \left\{[L1(j)\cdot RATE4 + L2(j)\cdot RATE5 + K(j)]\cdot DEVQ + S(j)\cdot RATE4\right\}/DEVQ \tag{3.7}$$

where: $PCER_2$ = Total Screening Cost per Device Type

$L_1(j)$ = Engineering labor for device category j (Hrs.)

$L_2(j)$ = Technician labor for device category j (Hrs.)

TABLE 3.2.3-1 DEVICE SCREENING LABOR AND COST FACTORS

DEVICE SCREEN/PROCESSING	METHOD & TEST CONDITION	NON-MEMORY SSI/MSI			MEMORY SSI/MSI			LSI		
		LABOR (HRS.)		COST ($)	LABOR (HRS.)		COST ($)	LABOR (HRS.)		COST ($)
		ENGINEERING	TECHNICIAN		ENGINEERING	TECHNICIAN		ENGINEERING	TECHNICIAN	
Stabilization Bake (No End point Measurements Required)	1008, 24 Hrs. Min. Test Condition C Min	--	.0005	--	--	.0005	--	--	.0005	--
Temperature Cycle	1010, Test Condition C	--	.0005	--	--	.0005	--	--	.0005	--
Constant Acceleration	2001, Test Condition E (Min) Y1 Orientation only	--	.02	--	--	.02	--	--	.02	--
Seal: A) Fine	1014	--	.04	--	--	.04	--	--	.04	--
B) Gross			.04	--	--	.04	--	--	.04	
Interim Electrical	Per Applicable Device Specification	.01	.02	--	.01	.04	--	.04	.24	--
Burn-In:	1015, 160 Hrs. at 125°C Min.	--	.01	--	.02	.01	--	.04	.04	--
A) Sockets		--	--	--	--	--	11.75	--	--	53.00
B) Components		--	--	--	--	--	2.00			12.00
C) Materials		--	--	--	--	--	--	--	--	7.00
Final Electrical	Per Applicable Device Specification	.00917	.05	--	.02417	.22	--	.04417	.6	--
External Visual	2009	--	.05	--	--	.05	--	--	.05	--
Clerical		--	.02	--	--	.02	--	--	.02	--
Serialization		--	.04	--	--	.04	--	--	.04	--
Data Log Delta Measurements		--	.1	--	--	.1	--	--	.1	--
Marking		--	.02	--	--	.02	--	--	.02	--
Totals Per Device		.01917	.411	--	.05417	.601	13.75	.12417	1.191	72.00

TABLE 3.2.3-2 CER DATA FOR DEVICE SCREENING

CER	ENGINEERING LABOR (HRS.) $L_1(j)$	TECHNICIAN LABOR (HRS.) $L_2(j)$	OTHER CHARGES ($) K(j)	SENTRY SOFTWARE FOR NEW DEV. S(j)
Non Memory SSI/MSI	0.0192	0.411	--	20
Memory SSI/MSI	0.0542	0.601	13.75	80
LSI	0.1242	1.191	72.00	180

K(j) = Total other costs for device category j ($)

S (j) = Engineering labor to program the Sentry Tester for new devices for Device category j (Hrs.)

RATE4 = Engineering labor rate ($/HR)

RATE5 = Technician labor rate ($/HR)

3.2.4 CARD ASSEMBLY ($PCER_3$)

The card assembly process consists of 1) card kitting where all devices (MC devices plus supporting non-MC devices) defined for a unique card function are brought together for assembly, 2) card preparation (etch), 3) device lead preparation and tining, 4) axial and DIP insertion, and 5) device mounting (e.g., machine wave solder and/or hand solder). Rather than develop a single CER describing MC device purchase as part of the card assembly cost, separate CERs were developed to take advantage of separate sources of data in which:

(1) the sample size of device purchase costs could be much larger, and
(2) a greater number of independent MC characteristic could be considered as variables.

Thus, the card assembly CER does not contain the cost of MC devices but does include the cost of all supporting non-MC devices.

The basic sources of data for the card assembly CER were the Project Assembly Cost Reports. These reports allocate material and over-all assembly costs of specific cards (by part number) with known MC characteristics. MC material costs were deleted from these reports (to avoid "double counting MC procurement cost), and the remaining data (including the cost of supporting non-MC devices) were then regressed against the known MC characteristics of the corresponding card.

Two variables were found which correlated significantly with card assembly cost (see Table 3.2.4-1). Not surprising, the number of devices per card (NDEV) is the most significant single MC factor relating to card assembly costs. The number of

TABLE 3.2.4-1 CARD ASSEMBLY VARIABLE DESCRIPTION

VARIABLE	DESCRIPTION	UNITS	RANGE
CER	Card Assembly Cost Per Card	$	369.62 - 1627.36
NDEV	Number of Devices Per Card	Qty.	39 - 290
NRAM	Number of RAMS Per Card	Qty.	0 - 24

random access memory devices (NRAM) contained on a card was the only other MC factor that explained any additional cost variation.

Nineteen candidate variables were tested in the step-wise regression procedure using twenty two data points each one of which represented a historical average (i.e., each value of the dependent variables represents the assembly cost per card averaged over all cards of that type produced over a period of time). However, none of these variables had any appreciable correlation with assembly cost over that already explained by NDEV and NRAM.

The applicable CER's and corresponding R-values are given in Table 3.2.4-2. The complete regression runs are given in Appendix A-3. Basic CER for estimating assembly cost per card is given by:

(3.8) $PCER_3 = 5.91634 \cdot NDEV + 27.57201 \cdot NRAM$

This CER states that the assembly cost per card is approximately $6 per device. If RAM devices are used, an additional cost of $28 per RAM device is incurred.

TABLE 3.2.4-2 CER'S FOR CARD ASSEMBLY

CER	CONSTANT	INDEPENDENT VARIABLE		R	VARIABLES REMOVED
		NDEV	NRAM		
	C1	C2	C3	--	--
BASIC	0	5.91634	27.57201	.98	--
1	0	6.26267	--	.95	NRAM

$PCER_3 = C_2 \cdot NDEV + C_3 \cdot NRAM$

3.2.5 TEST-REWORK CYCLE ($PCER_4$)

3.2.5.1 CARD TEST LABOR CER

Three sources of plant level data were used to derive the CER:

- Card Test Defect Analysis (CTDA) reports,
- Assembly Area Quality Level (AAQL) reports and,
- Card level parts lists used with respect MIL-HDBK 217C for making reliability predictions.

For each program in manufacture the CTDA report lists: 1) the number of cards reworked (distinguished by function as linear or digital but not by part number); 2) the defect distribution $D(d_1, d_2, \ldots, d_{10})$ of these cards across ten standard defect codes, d_i, $1 \le i \le 10$; and 3) average test hours per card, H. Using 14 such summaries, regression equations depicting test hours per card as a function of defect distribution were developed, that is, each equation defines a function such that:

$$H = F(D(d_1, d_2, \ldots, d_{10}))$$

Regression equations with high correlation ($R > .95$) were found for six systems.

The second source of data (AAQL reports) defined the defect distribution, say $D^*(d1, d2, \ldots, d10)$ of specific card types (by part number) over the same period of time. By selecting card types with various quantities of MCs and using the regression equations, the average number of labor hours expended to test each card type was determined; that is, new values of H were computed according to the equation:

$$H = F(D^*(d_1, d_2, \ldots, d_{10}))$$

Thus, H is now a relationship between card average test hours and specific card types (by part number).

Finally, the third source of data, card level parts list data, provided the MC characteristics ie, technology, quality grade, packaging etc of each card type. These MC characteristics were treated as independent variables and H as the dependent variable in the regression.

Table 3.2.5-1 identifies the card characteristics relating to MC devices that were significantly correlated with H. Twenty eight data points representing historical averages were used. The variable representing the product of population times number of digital gates (NDEV·NDG) was found to explain most of the variation (approximately 36%) in card test labor. The applicable card test labor CER's and their corresponding R-values are given in Table 3.2.5-2. The complete regression runs are provided in Appendix A-4.

TABLE 3.2.5-1 CARD TEST LABOR VARIABLE DESCRIPTION

VARIABLE	DESCRIPTION	UNITS	RANGE
H	CARD TEST HOURS PER CARD	HRS	.64 - 12.18
NDEV	NUMBER OF DEVICES PER CARD*	QTY	42 - 524
NMC	NUMBER OF MC DEVICES PER CARD	QTY	12 - 144
NDG	NUMBER OF DIGITAL GATES PER CARD	QTY	0 - 2940
NLG	NUMBER OF LINEAR GATES PER CARD (TRANS/4)	QTY	3.50 - 132.50
W	CONTRIBUTION OF MC DEVICES TO CARD FAILURE RATE	RATIO	.02 - 1.00

*Total active and passive devices.

TABLE 3.2.5-2 CER's FOR CARD TEST LABOR

	INDEPENDENT VARIABLE						
CER	CONSTANT	NDEV·NDG	1-W	NLG	$(NMC/NDEV)^2$	R	VARIABLES REMOVED
	C1	C2	C3	C4	C5	---	----------
BASIC	-.29669	.00000889	4.99908	.01514	1.98307	.84	----------
1	.37016	.00000891	5.13788	------	-------	.81	NLG, $(NMC/NDEV)^2$

$$H = C1 + C2 \cdot NDEV \cdot NDG + C3 \cdot (1-W) + C4 \cdot NLG + C5 \cdot (NMC/NDEV)^2$$

3.2.5.2 CARD TEST FRACTIONAL YIELD CER (Yc)

The AAQL report described previously provided the fractional yield of tested card types with known MC characteristics. Table 3.2.5-3 identifies the card characteristics relating to MC devices that provided significant correlations with card test yield (Yc). Twenty three data points representing historical averages were used to derive the applicable card test yield CER's. These are given in Table 3.2.5-4 with the corresponding R-values. The completed regression runs are given in Appendix A-5.

TABLE 3.2.5-3 CARD TEST FRACTIONAL YIELD VARIABLE DESCRIPTION:

VARIABLE	VARIABLE DESCRIPTION	UNITS	RANGE
Yc	CARD TEST YIELD	RATIO	.42 - .92
NMC	NUMBER OF MC DEVICES PER CARD	QTY	42 - 524
NDEV	NUMBER OF DEVICES PER CARD	QTY	28 - 255
QB2	NUMBER OF MC DEVICES PER CARD OF QUALITY GRADE B2 OR LOWER	QTY	0 - 144
NLG	NUMBER OF LINEAR GATES PER CARD	QTY	0 - 132
W	CONTRIBUTION OF MC DEVICES TO CARD FAILURE RATE	RATIO	.37 - .99

TABLE 3.2.5-4 CER's FOR CARD TEST FRACTIONAL YIELD

CER	INDEPENDENT VARIABLE					R	VARIABLES REMOVED
	CONSTANT	(NMC/NDEV)	QB2	NLG	1-W		
	C1	C2	C3	C4	C5	---	-----------
BASIC	0	-.20504	-.00146	-.00122	-.14842	.90	-----------
1	0	-.31298	-------	-------	-------	.78	1-W, QB2, NLG

$$Y_c = 10^{(C2\cdot(NMC/NDEV) + C3\cdot QB2 + C4\cdot NLG + C5\cdot(1-W))}$$

3.2.5.3 CARD REWORK COST FACTOR (c_1)

The labor required to rework a card (ie, the labor for removing and replacing defective MC Devices once a failure has been isolated with test equipment), TCR, does not appear to vary significantly with changes in MC characteristics on the card except indirectly through card test yield. Based on manufacturing engineering estimates, an average of 0.26 hours is expended for removing/replacing defective devices. Thus, each failed card incurs a rework cost (c_1) of:

$$c_1 = TCR\cdot RATE1$$

where: TCR = 0.26 hours per rework action.

RATE1 = Technician labor rate during card test ($/hr.)

3.2.5.4 SYSTEM TEST FRACTIONAL YIELD CER (Ys)

Data for the system (i.e., higher assembly) test fractional yield CER was assembled from two sources before processing. The Indentured Parts Lists (IPL's) of systems give the quantity of cards (by part number) used in a system. By comparing the IPL's with the Abbreviated Failure Reports employed by systems using Hughes' Failure Reporting and Corrective Action System (FRACAS), it was possible to create a data base giving the system yield (Ys) as the dependent variable for specific cards with known MC characteristics.

Table 3.2.5-4 identifies the card characteristics relating to MC devices that provided significant correlations with system test yield. Thirteen candidate variables were tested in the stepwise regression procedure using twenty two data points. The total number of devices per card (NDEV) explained most of the variation in system test yield (approximately 65%).

Table 3.2.5-5 provides the applicable system test yield CER's and corresponding R-values. Although the alternate CER given in the table provides an alternate for computing system test yield, this CER is not used in the LCC model. This is because other CER's require the number of MC devices as an essential input. The complete regression runs for these CER's are given in Appendix A-6.

TABLE 3.2.5-5 SYSTEM TEST YIELD VARIABLE DESCRIPTION

VARIABLE	DESCRIPTION	UNITS	RANGE
YS	SYSTEM TEST YIELD PER CARD	RATIO	.74 - .96
NMC	NUMBER OF MC DEVICES PER CARD	QTY	3 - 58
NDEV	NUMBER OF DEVICES PER CARD	QTY	30 - 160

TABLE 3.2.5-6 CER's FOR SYSTEM TEST YIELD

CER	INDEPENDENT VARIABLES			R	VARIABLES REMOVED
	CONSTANT	NDEV	NMC		
	C1	C2	C3	---	--------
BASIC	0	-.00094	-.001	.83	--------

$$Y_s = EXP(C2 \cdot NDEV + C3 \cdot NMC)$$

3.2.5.5 SYSTEM REWORK COST FACTOR (c_2)

Each failure at the system level necessitates technician time for fault isolation and card replacement. These tasks depend on technician skill level and complexity of the fault isolation process, factors which are independent of MC characteristics and which vary according to system design and complexity. Moreover, these factors cannot be quantized from existing card-level data. In order to account for system repair time when an MC device causes the failure, system test technicians were interviewed. This resulted in an estimated average time from fault detection to resolution and check-out of approximately 0.5 hours per repair action. Thus each card failing system test incurs a rework cost (c_2) of:

$$c_2 = \mathrm{TSR} \cdot \mathrm{RATE2}$$

where:

TSR = 0.5 hours per rework action

RATE2 = composite labor rate at systems test ($/hour)

3.3 MAINTENANCE AND SUPPORT

3.3.1 MAINTENANCE AND SUPPORT COST MODEL

Microcircuit characteristics are an important contributor to the lifetime maintenance and support costs of modern military systems. The impact of microcircuit alternatives on the lifetime support costs (a major component of LCC) cannot be assessed completely without accounting for the effects on system spares, support equipment, inventory entry and supply management costs, and other support areas where changes in device characteristics affect the next level of assembly (i.e., card, module, assembly, etc.). For example, in comparing alternate methods of system design implementation such as standard SSI/MSI versus custom LSI, the total number of card types needed to implement a given function would be higher for one alternative than for the other. In this case, the inventory entry (i.e., into government inventory) and supply management costs would, of course, be higher for the alternative which required more device and card types. Moreover, initial spares stockage and support equipment costs may also be higher. Thus, if only the microcircuit's impact on system acquisition is considered, an erroneous decision could be made because major maintenance and support cost impacts were ignored.

Figure 3.3.1-1 describes the maintenance support model and identifies the contributing cost factors which are influenced by changes in MC characteristics. The model shows two levels of maintenance: the organizational level where M sites are maintained with on-site spares and supply management and the depot where all card repair actions are performed. The logistics pipeline between sites and depot is supported with an initial spares stockage based on the repair cycle time and spares replenishment due to supply leakages. In this two-level maintenance model, fault isolation to the card or card group takes place on-site and card repair takes place at the depot.

In a three-level maintenance situation where an intermediate repair facility is inserted between the site and the depot, higher assemblies (units) are typically spared on site. Thus, when a failure occurs, the entire unit is removed and sent to the intermediate facility where the failed card is then removed from the unit and sent to the depot for repair. For purposes of estimating MC cost impacts, this three-level maintenance model can be approximated using the two-level model by co-locating the intermediate with the organizational site or depot, as appropriate, and adjusting 1) the false-return rate (i.e., pulling a "unit's" worth of cards for a single card failure), 2) the spares order-ship time and 3) the depot repair cycle time.

Each of the maintenance support cost factors and their relationship to changes in MC characteristics are discussed in Subsections 3.3.2 through 3.3.7.

3.3.2 SPARES ($MCER_1$)

A change in MC characteristics such as device quality grade, standard SSI/MSI to custom LSI, etc. can have major impacts on partitioning the system design functions into units, assemblies and cards as well as reliability and production cost. On-site system sparing (e.g., cards) is a direct consequence of this partitioning since it defines the numbers and types of cards being utilized.

The Algorithm given below computes initial stockage, pipeline and the lifetime replenishment spares due to pipeline leakages (i.e., losses due to transit damage, condemnation, etc.). This Algorithm computes recurring and the non-recurring

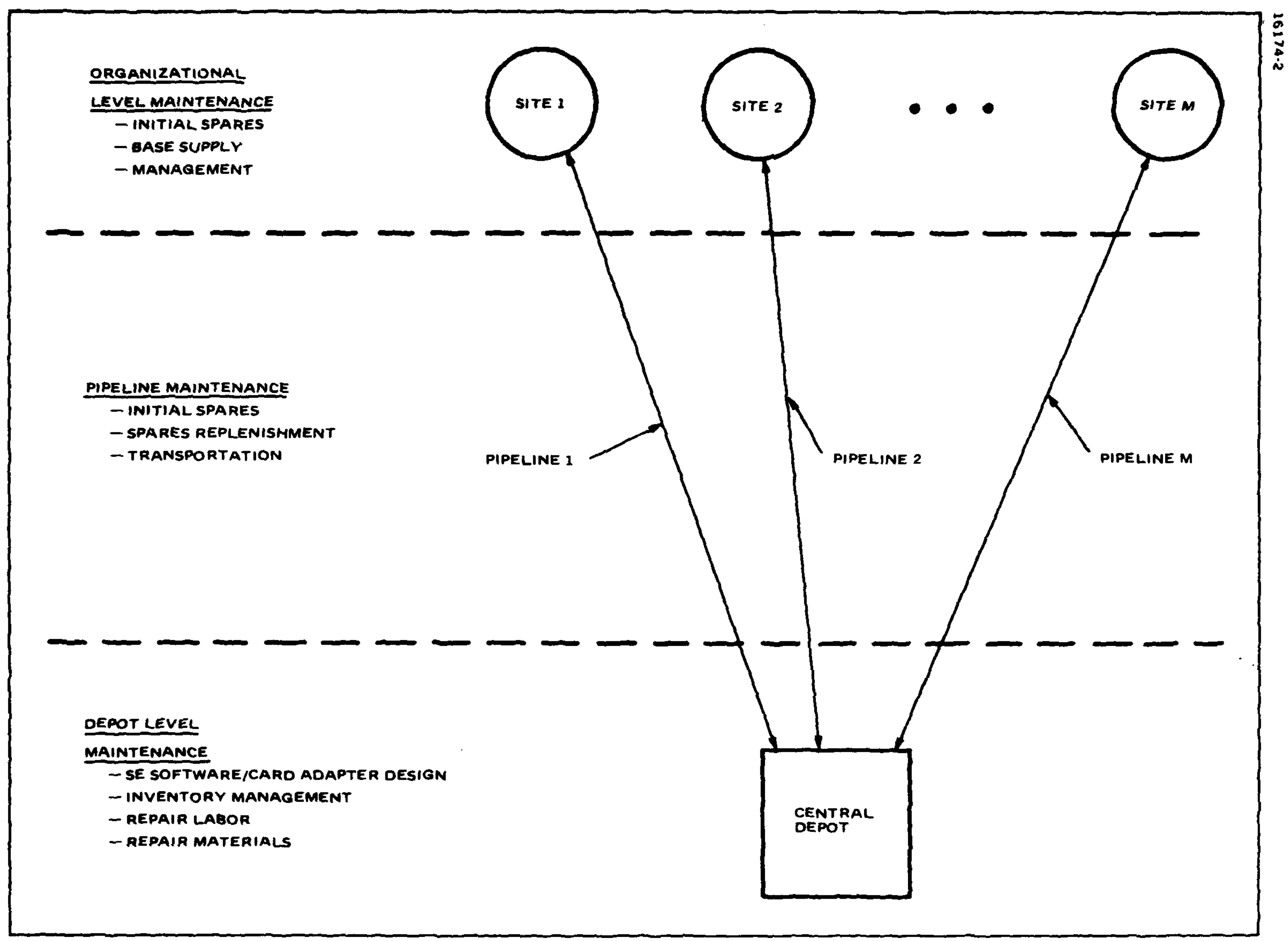

Figure 3.3.1-1. Maintenance Support Model

costs for each card type and then sums the results over N_c distinct card types. The non-recurring costs represented in the algorithm reflect first year spares stockage costs. The recurring costs of replenishment spares are distributed over operating lifetimes of 5, 10 and 15 years. The card failure rate (CF) can be adjusted to account for false returns (Fc). The average stock function (X) is based on the Poisson failure distribution and a minimum site stock safety factor (PL) where the demand (A) is derived from the card failure rate, order-ship time (Ts) and the false return adjustment Factor.

$$(3.9) \qquad MCER_1(y) = M\sum_{i=1}^{Nc}\left(X(i) + y \cdot \frac{To(1+Fc)}{M} \cdot CARD(i) \cdot CF(i) \cdot \left(\frac{T_R}{8760} + W(i) \cdot D\right)\right) \cdot K_c(i)$$

where:

M = Number of sites for spares stockage

$K_c(i)$ = Card Cost of i^{th} card type (see below)

T_R = Repair cycle time (Hours)

T_o = Operating hours per year (Hours)

Fc = False Return Factor (Number of false returns per failure)

Card(i) = Total quantity of cards used, i^{th} card Type

CF(i) = Failure rate of i^{th} card type

W(i) = Ratio contribution of MC devices to card failure rate

D = Condemnation rate

X(i) = Site spares stockage. Minimum value such that:

$$\sum_{j=0}^{X(i)} e^{-A(i)} A(i)^j/j! \geq P_L^{1/Nc}$$

$A = Ts \cdot (card(i)/M) \cdot CF(i) \cdot (1 + F_c)$

P_L = Stock Safety Factor

Nc = Number of distinct card types.

T_s = Order-ship time (Hours)

The unit cost of a spare, $K_c(i)$, is computed based on card type except for the material cost of the MC devices which is averaged:

$$K_c(i) = (PCER_1 + PCER_2) \cdot NMC(i) + MANU\$(i)$$

where:

$PCER_1$ = total MC device procurement cost (See Section 3.2.2)

$PCER_2$ = total MC device screening cost (See Section 3.2.3)

$NMC(i)$ = number of MC devices used on i^{th} card type

$MANU\$(i)$ = manufacturing cost of i^{th} card type (i.e., assembly and test cost)

The spares cost represented by the above algorithm is driven primarily by the number of operating sites (M) and the number of card types (N_c). The number of sites acts as a simple multiplier of the spares cost at a single site. The number of card types, however, plays an even more significant role in that it also affects the assurance spares for each card type (i.e., the factor $P_L^{1/Nc}$ increases causing $X(i)$ *to increase as* N_c *increases*). Similarly, the expected number of false returns per failure (Fc) can have a significant impact on spares cost since it multiplies the demand, A(i), as well as the pipeline and replenishment spares. Of course, the other factors in the algorithm can also change resulting in significant cost impacts, but they are not as likely to change as radically as M, N_c or F_c.

3.3.3 SUPPORT EQUIPMENT ($MCER_2$)

Adapters for circuit card testers (e.g., the General Radio 1796 card tester) are generally required for each new card type or family of card types. Similarly, the diagnostic software used in programmable testers must be developed for each new card type. These costs are clearly a function of the card complexity, packaging and density (devices per card), and, therefore, are valid candidates for microcircuit CERs.

$$(3\text{-}10) \quad MCER_2 = \sum_{J=1}^{N_c} (KA(I) + KS(I))$$

where:

N_c = Number of Distinct Card Types

$KA(I)$ = Software equipment adapter cost for card type I.

$KS(I)$ = Software diagnostic development cost for card type I

Table 3.3.3-1 provides a range of factors for software development cost per card and adapter cost per card based on the type of card (digital or linear) and level of complexity. The higher cost values shown in the table, particularly in the case of linear cards, are greatly affected by test complications resulting from unusual signal conditioning requirement, RF problems and security requirements (e.g., COMSEC). Multi-layer circuit boards also complicate testing and thereby increase software and adapter costs.

TABLE 3.3.3-1. SOFTWARE AND ADAPTER DEVELOPMENT COSTS (K$)

Card Complexity		Software Cost (KS)		Adapter Cost (KA)	
Linear*	Digital**	Linear	Digital	Linear	Digital
15-20	Non Memory	10-25	4-6	3-5	.5-2
20-50	SSI, MSI	20-40	-	5-7	-
50-250	Memory and LSI	40-80	6-10	10-15	.5-2

*Number of linear MC devices per card.
**Independent of the number of devices per card.

3.3.4 INVENTORY ENTRY AND SUPPLY MANAGEMENT ($MCER_3$)

For a new system, the government incurs an initial cost of entering all new pieceparts, cards, assemblies, etc. into the Federal Stock System and a recurring cost of maintaining these items in inventory for the system's life cycle. In addition, a recurring base supply management cost may also be incurred for every item stocked on-site.

Since a change in device characteristics may also change the number of card types. For example, a change from standard SSI/MSI devices to custom or semi-custom LSI would require a repartitioning of the system into units, assemblies and cards. This would introduce new (LSI) items into inventory but also would likely result in a reduction in card types. Depending on the number of sites, the reduction in card types may result in sufficient reduction in base supply management costs to swing the tradeoff in favor of LSI.

The following algorithm is used to estimate lifetime (y) inventory management costs based on the introduction of new MC devices (D_{NEW}) and cards (Nc) into government inventory and M base supply systems:

$$MCER_3(y) = (D_{NEW}+N_c)K_I + y\left[\left(D_{NEW}+N_c\right)K_{IR} + M\cdot N_c\cdot K_{SM}\right] \quad (3.11)$$

where:

D_{NEW} = Number of new MC device types.

N_c = Number of new card types.

K_I = Government Inventory Entry Cost Factor ($/Item)

K_{IR} = Recurring Government Inventory Management Cost Factor ($/Item/Year)

K_{SM} = Recurring Government Supply Management Cost ($/Item/Site/Year)

M = Number of Operating Sites

The cost factors K_I, K_{IR} and K_{SM} are government derived and depend on the type of support system in use. It should be noted that cards only are put in the M base supply systems. Table 3.3.4-1 provides the values (used as defaults) currently employed in the LCC model:

TABLE 3.3.4-1 COST FACTORS FOR INVENTORY MANAGEMENT

FACTOR	VALUE*($)
Inventory Entry (K_I)	54
Recurring Inventory Management (K_{IR})	128
Recurring Base Supply Management (K_{SM})	42

*Based on LCC data currently used in cost analyses for the Joint Surveillance System (JSS), Headquarters Electronic Systems Division (AFSC) Hanscom AFB.

3.3.5 REPAIR LABOR ($MCER_4$)

When a microcircuit device fails, the card that contains the device (and possibly other cards as well, depending on fault isolation capability) is removed from the system and transported to a repair facility where the failure is verified and the failed device is isolated, removed and replaced. The repaired card is then checked out and put back into spares stock. The frequency of repair is determined from the card failure rate (CF), false return adjustment factor (F_c), operating hours per year (T_o) and the card usage population (CARD). The average labor hours to perform the repair action is dependent on whether the card is a false return. A false return incurs L_F labor hours and a failed card incurs L_R labor hours. The repair labor is a function of device complexity, card density and the capability of the Depot support equipment.

The following algorithm is used to estimate depot repair labor cost based on the expected number of returns over the lifetime (y) of the system and data on card repair labor.

$$(3.12) \quad MCER_4(y) = T_o K_R y \sum_{i=1}^{Nc} CARD(i) \cdot W(i) \cdot CF(i) \cdot \left(L_R(i) + L_F(i) \cdot F_c \right)$$

where:

T_o = Operating Hours Per Year

K_R = Depot Labor Rate (Depot overhead should be included in this rate in order to reflect "true" cost to the government)

Nc = Number of card types

CARD(i) = Total quantity of cards of i^{th} type

W(i) = Ratio contribution of MC to card failure rate, i^{th} card type

CF(i) = Card Failure Rate, i^{th} type

$L_R(i) = T_{CR} + H(i)$

T_{CR} = Card Rework labor (see Section 3.2.5.3)

H(i) = Card Test Labor (See Section 3.2.5.1)

$L_F(i)$ = Average Labor to Verify Fault.

The estimated value for $L_F(i)$ is dependent on card type (i.e., linear or digital and was derived from Hughes manufacturing test engineering experience:

$$L_F(i) = \begin{cases} 1.5, \text{ Hours For Digital Cards} \\ 3.0, \text{ Hours For Linear and Mixed (Linear-Digital) Cards} \end{cases}$$

The value for the Depot labor rate (K_R) is \$20/hour (used as a program default) and is based on Government data.[3]

3.3.6 REPAIR MATERIALS ($MCER_5$)

The average repair materials cost per card (K_M) associated with depot repair actions is based on applying a 5% factor to the estimated card cost. This factor is a government derived standard[3]. The estimated card cost includes device procurement cost per card, device screening cost, if applicable, assembly cost

per card and the test cost per card. The following algorithm is used to estimate the lifetime (y) depot repair materials cost.

$$MCER_5(y) = YT_o \sum_{i=1}^{Nc} CARD(i) \cdot W(i) \cdot CF(i) \cdot K_M(i) \tag{3.13}$$

where:

T_o = Operating Hours Per Year

N_c = Number of Card Types

CARD(i) = Total Quantity of Cards Used, i^{th} Card Type.

W(i) = Ratio Contribution of MC Devices to Card Failure Rate, i^{th} Type.

CF(i) = Card Failure Rate, i^{th} Type

$K_M(i) = 0.05 \cdot Kc(i)$, Repair Material Cost

$K_c(i)$ = Card Cost (See Section 3.3.2)

3.3.7 MAINTENANCE TRANSPORTATION ($MCER_6$)

The transportation costs associated with repair actions is based on the average shipping weight of a card (W_c) and an average shipping cost per pound (K_T). The factor W_c is design dependent and, therefore, user furnished data. The factor K_T is a government standard based on TTO-ORT-032-78-V3. False returns (F_c) also incur transportation costs and these are included in the estimate.

The following algorithm estimates the lifetime (y) transportation costs and is based on the two-way transportation of all cards removed (i.e., site-to-depot and return to site supply).

$$MCER_6 = 2T_oW_cK_T(1+F_c)y \sum_{i=1}^{Nc} CARD(i) \cdot CF(i) \cdot W(i)$$

T_o = Operating Hours Per Year.

W_o = Average Shipping Weight of a card (lbs).

K_T = Average Shipping Cost ($/lb).

CARD(i) = Total Quantity of Cards Used, i^{th} Card Type

CF(i) = Card Failure Rate, i^{th} Type.

W (i) = Ratio Contribution of MC Devices to Card Failure Rate.

3.4 OTHER MC COST CONSIDERATIONS

The LCC of MC devices must also take into account perturbations to the "normal" acquisition and support process. The cost of acquisition depend upon purchasing characteristics (i.e., device availability in the desired quality grade, quantities, etc.) standardization status, military qualification, risk of obsolescence and whether the device manufacturer deals in off-shore procurements. When these factors are present, their cost impacts must be taken into account together with the MC characteristics discussed in the previous sections. The following paragraphs discuss the general impact of these considerations on MC devices.

3.4.1 LEARNING CURVE EFFECTS

The cost of most MC devices are generally set by pricing agreements between supplier and contractor on a yearly basis. For low volume, custom or semi-custom devices, learning curves are usually established in RDT&E on a low volume of devices. Learning curve entry points and slopes are then established on the basis of these device specifications and the characteristics of manufacturers' unique production process. For example, if the manufacturer's production process is typified by log-linear learning*:

$$Y(n) = AN^{\alpha}$$

where: $Y(n)$ = Cost of the n^{th} unit

A = Cost of the theoretical first unit

$\alpha = \ln S/\ln 2$

S = Learning curve slope

then A can be determined from the cost of, say, the first K units (i.e., $Y(k)$). With a knowledge of S determined by the manufacturer's production history, prices can be projected for any desired quantities (n) using:

$$Y(n) = Y(k)\left(\frac{n}{k}\right)^{\alpha}$$

3.4.2 COST OF SPECIFICATIONS, DEVICE QUALIFICATIONS

Documentation and qualification of MC devices to military standards can discourage many suppliers from bidding on military LSI developments. Accordingly, the military purchase typically only represents about 9% of the supplier's total procurement. The cost to develop a device specification and negotiate a procurement with a supplier can range from $1000 to $2000 (FY 80) per device, depending on the complexity of the device. The low end represents a simple SSI/MSI and the upper cost represents a custom LSI. Qualifying a device to JANB or space level can be

*Learning curves are discussed in some detail in TTO-ORT-032A-78-V3.

a significant problem. Normally, a supplier will agree to qualify to JANB or higher only on high-volume devices. If the supplier agrees, the cost to qualify is typically \$100K to \$150K for a first-time qualification.

3.4.3 ON-SHORE/OFF-SHORE PROCUREMENTS

Many device suppliers have off-shore facilities due to the substantial differences in labor rates. For example, labor rates of \$22 - \$25 per hour in the U.S. versus rates of \$1.10 - \$1.50 per hour in Taiwan. These differences in labor rates obviously give suppliers with large-off-shore commitments the capability of being more competitive than those with smaller or no off-shore commitments.

Companies with only on-shore commitments, however, tend to have much better lead times than those companies with both on-shore and off-shore. Part of the reason for this is that for devices produced in foreign countries, qualification and final assembly must be conducted in the U.S. in order to qualify as a military standard. Moreover, at the present time all JAN operations must be conducted on shore.

Most military equipment contractors do not deal directly with an off-shore supplier so that the affect on the MC device purchase cost is obscured by multiple sourcing and competition among suppliers.

3.4.4 DEVICE OBSOLESCENCE

When a manufacturer puts out notifications that a device will no longer be produced, the buyer is left with several options. These options are usually never clear cut since many factors must be considered in order to make a decision. The major factors include the number of manufacturers producing these parts, the use of the system(s) involved, the number of systems involved and the extent of the usage of the part in the system.

When a manufacturer discontinues production of a MC device, the buyer is given the option of purchasing a "lifetime" supply of these parts in one last order, thus incurring a large capital investment and a risk in not accurately estimating the quantity of parts needed.

The buyer may also procure parts from other suppliers. But, as the number of suppliers discontinue production, the cost of buying these parts can run up to three or four times the original procurement price. Moreover, the turnaround time for these parts can take up to as long as a year per order.

Normally, substitute devices providing the same function as the previous device may be purchased. These replacements are generally superior (and more costly) to the discontinued part. The problem with this option is that a large expense is sometimes incurred in preparing the paperwork needed to implement this new part into configuration control. Although these redesign changes can be very expensive, they are usually preferred over the other options in high usage situations.

Section 4.0

APPLICATION PROCEDURE AND EXAMPLES

4.1 GENERAL PROCEDURE

4.1.1 INPUT DATA REQUIREMENTS AND PROGRAM DEFAULTS

The data input requirements and default options for the MC LCC Model are described in Tables 4.1.1-1, 4.1.1-2, and 4.1.1-3. These tables describe the input requirements and default options for the three input data sets necessary to run the LCC Model computer program.

The first column of the tables describes variable names for each of the data sets. The names are listed in the order that they must appear in the data sets. The second column gives the description of variable. The third column gives the required units for each variable in the program. The fourth column describes the inputs necessary to exercise the default options. A dash in this column indicates that no default options are available to the user. A "0" or "-1" in this column initiates the default value indicated. The fifth and sixth columns describe what values or conditions are used in the program when a default is exercised. If a default equation is employed, the CER's that are affected are noted. Conditions under which the program will terminate are also provided.

Definition of Input Data Sets – The following general operational description applies to all procedures for processing input data and execution of the LCC Model on an AMDAHL 470 or IBM 360/370 Computer System with a Time Sharing Option (TSO). Information for the LCC Model are created by three data sets noted below. The asterisks denote that the associated parameter has a default value or CER equation supplied in the model.

FILE 01-Program. Data – This data set contains values for the parameters: N, NC, FSTD*, CMAX*, RATE4*, RATE5*, RATE1*, RATE2*, RATE3*, M*, TS*, PL*, TO*, TR*, FC*, D*, KI*, KIR*, KSM*, KR*, KM*, KT*, WC*, RD*, RI*, YRDTE*, TRDTE*, YMANU*, TMANU*, YOAS*. (Refer to Table 4.1.1-1)

FILE 02-Device. Data – This data set contains values for the MC device characteristics found on each MC device type. For each device type, an array

Table 4.1.1-1. INPUT REQUIREMENTS & OPTIONS FOR PROGRAM DATA

VARIABLE	VARIABLE DESCRIPTION	INPUT UNITS	DEFAULT OPTIONS		PROGRAM OPTIONS/COMMENTS
			INPUT	DEFAULT	
N	Number of distinct MC device types	Qty	–	None	Program will terminate for inputs ≤ 0.
NC	Number of distinct card types	Qty	–	None	Program will terminate for inputs ≤ 0.
FSTD	Standardization factor for RDT&E	Qty	0	0	
CMAX	Maximum RDT&E Cost	$	0	203	See Note
CMIN	Minimum RDT&E Cost	$	0	24	See Note
RATE 4	Hourly burdoned rate for an engineering labor grade	$/hr.	0	43.75	See Note
RATE 5	Hourly burdoned rate for a technician labor grade	$/hr.	0	35	See Note
RATE 1	Hourly burdoned rate for the card test	$/hr.	0	26.90	See Note
RATE 2	Hourly burdoned rate for the system test	$/hr.	0	26.90	See Note
RATE 3	Hourly burdoned rate for the rework/retest	$/hr.	0	20.30	See Note
M	Number of sites for spares stockage	Qty	0	1	
TS	Spares ship time	Hrs	0	336	
PL	Stock safety factor	Qty	0	.9	
TO	Operating hours per year	Hrs/Yr	0	8760	
TR	Turn around time	Hrs	0	1440	
FC	False return factor	Qty	0	0	
D	Condemination rate	Qty	0	.05	
KI	Government inventory entry rate	$/item	0,-1	0, 54	See Note
KIR	Government inventory management cost	$/item/yr	0,-1	0, 128	See Note
KSM	Government supply management cost	$/item/site/yr	0,-1	0, 42	See Note
KR	Repair labor rate	$/hr.	0	20	See Note
KM	Repair Materials Cost per Maintenance Action	$/action	0	.05 Card$	Card$-card cost, which is computed internally
KT	Average shipping cost	$/lb.	0	.5	See Note
WC	Average shipping weight per card	lb	0	1	
RD	Discount rate	Qty	0	.1	
RI	Inflation rate	Qty	0	.06	
YRDTE	Year RDT&E starts	Qty	0	1980	
TRDTE	Number of years RDT&E lasts	Yrs	0	0	
MANU	Year Production starts	Qty	0	YRDTE + TRDTE	
MANU	Number of years Production lasts	Yrs	0	1	
YOAS	Year Operations and Support starts	Qty	0	YMANU + TMANU	

NOTE: Default value incurs an inflation factor

Table 4.1.1-2. INPUT REQUIREMENTS & OPTIONS FOR DEVICE DATA

VARIABLE	VARIABLE DESCRIPTION	INPUT UNITS	DEFAULT OPTIONS		PROGRAM OPTIONS/COMMENTS
			INPUT	DEFAULT	
NEW	MC device type i is a new device	1 if, 0 if not	–	None	Program will terminate for inputs < 0.
MEM	MC device type i is a memory device	1 if, 0 if not	–	None	Program will terminate for inputs < 0.
MOS	MC device type i is a MOS device	1 if, 0 if not	-1	Default Equation Supplied	Device Purchase (PCERI 3.2.2)
DIG	MC device type i is a digital device	1 if, 0 if not	-1	Default Equation Supplied	Device Purchase (PCERI 3.2.2)
ECL	MC device type i is an ECL device	1 if, 0 if not	–	None	Program will terminate for inputs < 0.
FP	MC device type i is a flat-pack	1 if, 0 if not	-1	Default Equation Supplied	Device Purchase (PCERI 3.2.2)
NG	Number of gates on MC device type i	Qty	–	None	Program will terminate for inputs < 0.
NB	Number of bits on MC device type i	Qty	–	None	Program will terminate for inputs < 0.
NP	Number of pins on MC device type i	Qty	–	None	Program will terminate for inputs < 0.
DEVQ	Total number of MC devices for MC device type i	Qty	–	None	Program will terminate for inputs ≤ 0.
REL	Reliability of MC device type i	*	–	None	Program will terminate for inputs ≤ 0.
SCRN	Screen MC device type i (100% Screening is assumed)	2 if, 1 if not	0	2	Device type i will be screened.

* The following reliability weights are used:

REL	0.5	1.0	3.0	6.5	8.0	17.5	35.0
QUALITY GRADE	A	B	B-1	B-2	C	C-1	D

Table 4.1.1-3. INPUT REQUIREMENTS & OPTIONS FOR CARD DATA

VARIABLE	VARIABLE DESCRIPTION	INPUT UNITS	DEFAULT OPTIONS		PROGRAM OPTIONS/COMMENTS
			INPUT	DEFAULT	
CARD	Total number of cards for card type i	Qty	–	None	Program will terminate for inputs ≤ 0.
NDEV	Number of active and passive devices on card type i.	Qty	–	None	Program will terminate for inputs ≤ 0.
NMC	Number of MC devices on card type i	Qty		None	Program will terminate for inputs ≤ 0.
NDG	Number of digital gates on card type i	Qty	–	None	Program will terminate for inputs ≤ 0.
NLG	Number of linear gates on card type i	Qty	-1	Default Equation Supplied	Card test hours (H 3.2.5), Card test yield (Yc 3.2.5), Repair Labor (MCER4 3.3.5)
NRAM	Number of rams on card type i	Qty	-1	Default Equation Supplied	Card Assembly (PCER3 3.2.4)
W	Ratio contribution of MCS to the card failure rate for card type i.	Qty	0	1	
CF	Card failure rate for card type i	Qty	–	None	Program will terminate for inputs ≤ 0.
KA	Support equipment adapter cost for card type i	$	0	0	
KS	Software diagnostic development Cost for card type i.	$	0	0	

(line) of 12 elements is generated which contains data for the parameters: NEW, MEM, MOS*, DIG*, ECL, FP*, NG, NB, NP, DEVQ, REL, SCRN*. (Refer to Table 4.1.1-2)

FILE 03-Card. Data – This data set contains values for the card characteristics found on each card type. For each card type an array (line) of 10 elements is generated which contains data for the parameters: CARD, NDEV, NMC, NDG, NLG*, NRAM*, W*, CF, KA, KS. (Refer to Table 4.1.1-3)

FILE 06-Output. Text – This data set contains the results of the LCC Model. An empty data set is created as a location for storage for the LCC results.

With the exception of FILE 06, all of the above files must be filled. If the defaults are to be exercised, proper default inputs must be used as specified in the tables. The input form for each of the above data sets is "unformatted" (i.e., the values for each record are simply separated by commas). This will be illustrated in the examples provided in Section 4-2.

Output Report – The output of the LCC program is separated into three sections, or tables. The first table describes the impact of MC devices on LCC in constant dollars (i.e., no inflation indicies or discount rates are applied) in the form of a cost breakdown structure. A breakdown into major contributing cost elements is provided for production (device procurement, screening and card manufacture) and maintenance support (spares, inventory management, depot maintenance, etc.), with the recurring costs distributed over life cycles of 5, 10 and 15 years.

The second table describes the impact of MC devices on LCC in constant, escalated and discounted dollars. The costs for each program phase are distributed over the scheduled duration of the phase: the recurring costs of a phase are apportioned equally over the time duration and the nonrecurring costs are incurred during the first year of the phase. The escalation and discount factors applied each year (based on user-provided rates or defaults) are also provided in this table.

The third table consists of three summaries of input data (program level, device level and card level) used to make an LCC estimate, including any default values that were employed.

All costs in the LCC summary tables are given in thousands of dollars. Some errors will occur due to round-off. These errors may be significant in cases where the computations result in annual costs less than $500, particularly if the program phase is multiple year. However, if annual costs of $500 are important to the analysis, the units can readily be changed (within the program) to whole dollars.

Diagnostics – If the total quantity of MC devices at the device level does not equal the total quantity of MC devices at the card level, an error message is printed stating the quantity of MC devices at each level. Similarly, if the total quantity of gates at the device level does not equal the total quantity of gates at the card level, an error message is printed stating the quantity of gates at each level.

4.1.2 STEP-BY-STEP GUIDE

The following steps are recommended as guidelines for executing the model program:

STEP 1 - Assemble required data for coding. Using Table 4.1.1-1 as a guide, determine user-unique values, default values, etc. Note that the parameters are ordered in the table according to the input sequence.

STEP 2 - Create the data files (sets) necessary for the model inputs and output.

FILE 01 (PROGRAM.DATA)

Col. No. 1

N, NC, FSTD, CMAX, CMIN,

RATE4, RATE5, RATE1, RATE2, RATE3,

M, TS, PL, TO, TR, FC,

D, KI, KIR, KSM, KR,

KM, KT, WC, RD, RI,

YRDTE, TRDTE, YMANU, TMANU, YOAS

FILE 02 (DEVICE.DATA)

Col. No. 1

NEW, MEM, MOS, DIG, ECL, FP, NG, NB, NP, DEVQ, REL, SCRN

↑

N Rows of Data (one for each device type)

↓

FILE 03 (CARD.DATA)

Col. No. 1

CARD, NDEV, NMC, NDG, NLG, NRAM, W, CF, KA, KS

↑

N_C Rows of Data (one for each card type)

↓

FILE 06 (OUTPUT.TEXT)

(This data set is empty)

$\boxed{\text{STEP 3}}$ - Allocate the data files for program execution:

FREE FI(FT06F001)

ALLOC FI(FT01F001) DA(PROGRAM.DATA)

ALLOC FI(FT02F001) DA(DEVICE.DATA)

ALLOC FI(FT03F001) DA(CARD.DATA)

ALLOC FI(FT06F001) DA(OUTPUT.TEXT).

$\boxed{\text{STEP 4}}$ - Program Execution. If MCF.MODEL has never been run before, it is necessary to compile and link the program before execution:

FORT MCF.MODEL. FORT

LINK MCA.MODEL.OBJ FORTL1B

CALL MCF.MODEL.LOAD

If the model has been run previously, it is only necessary to execute:

CALL MCF.MODEL

$\boxed{\text{STEP 5}}$ - Print the results of the program. If the results are to be printed at a terminal:

LIST OUTPUT.TEXT

If the results are to be sent to a line printer:

PRINTOFF OUTPUT.TEXT

4.2 EXAMPLES

4.2.1 DEVICE QUALITY EFFECTS ON LCC

For a population of typical high-density cards, the sensitivity of LCC to changes in device quality grades is examined. The "selected" population consists of 880 cards and is distributed over twenty (20) operating sites which are to be maintained over a 15 year period. With reference to the procedure described in Section 4.1.2 the detailed data is assembled and processed as follows:

$\boxed{\text{STEP 1}}$ - Assemble data for processing.

The data used consists of high-density digital, linear, and memory cards used in a typical Command-Control system. The "system" configuration supported at

each of the 20 sites is summarized in Table 4.2.1-1 and a detailed description of each card type subject to change is given in Table 4.2.1-2.

The input values and assumptions for PROGRAM.DATA are as follows:

- Number of card types and devices types (NC and N) are determined from Tables 4.2.1-1 and 4.2.1-2.
- Program default values are used for CMAX, CMIN, RATE4, RATE5, RATE1, RATE2, RATE3, TS, TO, TR, KI, KIR, KSM, KR, KM, KT, RD, RK, YRDTE and FSTD (see Table 4.1.1-1).
- The number of sites (M) is 20.
- The false return rate FC is 3 returns per failure.
- Comdemnation rate is assumed to be 0.05.
- Card weights are all assumed to be 1 lb each.
- Production start (YMANU) is assumed to be 1980 with a duration (TMANU) of 3 years.
- The operations and support phase is assumed to start in 1983.

The input values and assumptions for DEVICE.DATA are as follows:

- All the MC device types are off-the-shelf (i.e.: NEW=0).
- The input values for device characteristics MEM, MOS and DIG are determined from Table 4.2.1-2.
- All the MC devices are flat-packs (i.e.: FP=1)

TABLE 4.2.1-1. SYSTEM DATA FOR EXAMPLE -1

CARD DESCRIPTION	NUMBER OF CARD TYPES	QTY OF CARDS PER TYPE	TOTAL CARDS PER SYSTEM	TOTAL FOR 20 SITES
High Density Memory	1	5	5	100
High Density Digital	6	5	30	600
High Density Linear	3	3	9	180
Totals	$N_c = 10$		44	880

TABLE 4.2.1-2. CARD DATA FOR EXAMPLE -1

CARD TYPE	DEVICE DESCRIPTION	DEVICE TYPES EACH CATEGORY	DEVICE QTY PER TYPE	TOTAL DEVICES PER CARD	TOTAL GATES PER CARD (NG)	TOTAL FAILURE RATE PER CARD* (FAILURE/10^6 HOURS) (CF)			
						B	B-1	B-2	C
Digital Logic (DIG)	LSI (500 gates/device)	4	1	4	2000	.24	.72	1.56	1.92
	Digital Support Chips (10 gates/device)	10	5	50	500	.80	2.4	5.2	6.4
	Bipolar RAMS (1K BITS/device)	1	8	8	--	1.12	3.36	7.28	8.96
	Passive and Active Devices	--	50	50	--	.5	1.5	3.25	4.0
Totals for Digital Logic Cards		15		NDEV=112	2500	2.66	7.98	17.29	21.28
Linear	Linear (19 gates/device)	8	2	16	304	2.08	6.24	13.52	16.64
	SSI/MSI Digital (20 gates/device)	10	2	20	400	.32	.96	2.08	2.56
	Passive and Active Devices	--	100	100	--	1.0	3.0	6.5	8.0
Totals for Linear Cards		18		NDEV=136	704	3.4	10.2	22.1	27.2
Memory (MEM, MOS)	MOS RAMS (64K BITS/Device)	1	64	64	--	108.8	326.4	707.2	870.4
	SSI/MSI MOS Support Chips (20 gates/device)	5	2	10	200	.18	.54	1.17	1.44
	Passive and Active Devices	--	50	50	--	.5	1.5	3.25	4.0
Totals for Memory Cards		6		NDEV=124	200	109.48	328.44	711.62	875.84
Totals for All Cards		N=39							

*Per MIL-HDBK-217 assuming a ground-fixed environment.

- The number of gates for each device type is determined from Table 4.2.1-2.
- The number of bits (NB) for the RAMS used on the digital logic and memory cards is determined from Table 4.2.1-2.
- The pin count (NP) for SSI/MSI MC devices is 16 and the pin count for LSI devices is 40.
- The total number of MC devices (DEVQ) is calculated by multiplying the number of cards needed for the 20 sites in Table 4.2.1-1 by the device quantity per type in Table 4.2.1-2.
- The reliabilities are per MIL-HDBK-217 for quality grades B, B-1, B-2 and C (see Table 4.1.1-1).

The input values and assumptions for CARD.DATA are as follows:

- The total number of cards of each type (CARD) is calculated by multiplying the quantity of cards per type (Table 4.2.1) by the number of sites (20).
- The number of devices (NDEV) is determined from Table 4.2.1-2.
- NMC is the sum of the MC devices per card neglecting actives and passives (Table 4.2.1-2).
- NDG and NLG are determined by the device description (digital, linear) and the total number of gates of that type (NG) in Table 4.2.1-2.
- The number of RAMS per card (NRAM) is calculated by multiplying the number of cards needed for the 20 sites in Table 4.2.1-1 by the device quantity per type in Table 4.2.1-2 for RAM devices.
- W is calculated by dividing the sum of the MC device failure rates by the total card failure rate in Table 4.2.1-2.
- CF is calculated per MIL-HDBK-217 assuming a ground-fixed environment (Table 4.2.1-2).
- The support equipment adapter cost (KA) is assumed to be $1,000 for the total family of logic cards and $1,000 per card type for the linear and memory cards. Software development cost for support equipment (KS) is assumed to be $5,000 for the total family of digital logic cards, $60,000 per type for the linear cards and $8,000 per type for the Memory cards (see Section 3.3.3).

STEP 2 - CODE INPUT DATA.

The coding for the input data given below is for the effects of quality grade B on LCC. The coding of the input data for the other quality grades require appropriate changes in the reliability (REL) in File 01 and the card failure rate (CF) in File 02 (see Table 4.1.1-1 for REL values and Table 4.2.1-2 for CF values).

FILE 01 (PROGRAM.DATA)

```
Col. No. 1
↓
39,10,0.5,203,24,43.75,35,26.9,26.9,20.3,
20,336,0.95,8760,1440,3,0.05,54,128,42,
20,0,0.5,1,0.1,0.06,1980,0,1980,3,1983
```

FILE 02 (DEVICE.DATA)

```
Col. No. 1
↓
0,0,0,1,0,1,500,0,40,600,1.0,1
0,0,0,1,0,1,500,0,40,600,1.0,1
0,0,0,1,0,1,500,0,40,600,1.0,1
0,0,0,1,0,1,500,0,40,600,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,0,0,1,0,1,10,0,16,3000,1.0,1
0,1,0,0,0,1,0,1000,16,4800,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,0,0,1,19,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20.0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
0,0,0,1,0,1,20,0,16,360,1.0,1
```

```
0,1,1,0,0,1,0,64000,16,6400,1.0,1
0,0,1,1,0,1,20,0,16,200,1.0,1
0,0,1,1,0,1,20,0,16,200,1.0,1
0,0,1,1,0,1,20,0,16,200,1.0,1
0,0,1,1,0,1,20,0,16,200,1.0,1
0,0,1,1,0,1,20,0,16,200,1.0,1
```

FILE 03 (CARD.DATE)

Col. No. 01

```
100,112,62,2500,0,8,0.81,0.00000266,1000,500
100,112,62,2500,0,8,0.81,0.00000266,0,0
100,112,62,2500,0,8,0.81,0.00000266,0,0
100,112,62,2500,0,8,0.81,0.00000266,0,0
100,112,62,2500,0,8,0.81,0.00000266,0,0
100,112,62,2500,0,8,0.81,0.00000266,0,0
60,136,36,400,304,0,0.7,0.0000034,1000,60000
60,136,36,400,304,0,0.7,0.0000034,1000,60000
60,136,36,400,304,0,0.7,0.0000034,1000,60000
100,124,74,200,0,64,0.99,0.00010948,1000,8000
```

STEP 3 - Prepare to Run the Program.

```
free fi(ft06F001)

alloc fi(ft01f001) da(program.data)

alloc fi(ft02f001) da(device.data)

alloc fi(ft03f001) da(card.data)

alloc fi(ft06f001) da(output.text)
```

STEP 4 - Execute the Program.

```
CALL MCF.MODEL
```

STEP 5 - Print the Results of the Program.

```
PRINTOFF OUTPUT.TEXT
```

The LCC model output report giving the LCC effects using quality grade B MC devices is given in Table 4.2.1-3a, b, c. A similar set of tables (not shown) provides the LCC impacts using the other quality grades. A comparison of the quality grade effects taken from the model outputs is summarized in Table 4.2.1-4.

TABLE 4.2.1-3a EXAMPLE -1. MC DEVICE IMPACT ON LCC

MC DEVICE IMPACT ON LCC (THOUSANDS OF DOLLARS)

COST ELEMENT	CONSTANT DOLLARS 5 YEARS	10 YEARS	15 YEARS
RDT&E	0.	0.	0.
PRODUCTION	1539.	1539.	1539.
DEVICE PROCUREMENT	153.	153.	153.
DEVICE SCREEN	0.	0.	0.
CARD ASSEMBLY	1386.	1386.	1386.
OPERATIONS & SUPPORT	1408.	1893.	2378.
SPARES	1044.	1364.	1684.
SUPPORT EQUIPMENT	198.	198.	198.
INVENTORY ENTRY	51.	101.	151.
REPAIR LABOR	65.	130.	195.
REPAIR MATERIALS	50.	100.	150.
MAIN. TRANSPORTATION	0.	0.	0.
TOTAL COST	2947.	3432.	3917.

TABLE 4.2.1-3b EXAMPLE -1. LCC SUMMARY BY FISCAL YEAR

LCC SUMMARY BY FISCAL YEAR (THOUSANDS OF DOLLARS)

FISCAL YEAR	PROGRAM PHASE RDT&E	PROD	O&S	TOTAL DOLLARS	PRICE INDEX	INFLATED DOLLARS	DISC. FACT.	TOTAL COST
1980	0.	513.	0.	513.	1.000	513.	0.954	489.
1981	0.	513.	0.	513.	1.060	544.	0.867	472.
1982	0.	513.	0.	513.	1.124	573.	0.788	454.
1983	0.	0.	1020.	1020.	1.191	1215.	0.717	871.
1984	0.	0.	97.	97.	1.262	122.	0.651	79.
1985	0.	0.	97.	97.	1.338	130.	0.592	77.
1986	0.	0.	97.	97.	1.419	138.	0.538	74.
1987	0.	0.	97.	97.	1.504	146.	0.489	71.
1988	0.	0.	97.	97.	1.594	155.	0.445	69.
1989	0.	0.	97.	97.	1.689	164.	0.405	66.
1990	0.	0.	97.	97.	1.791	174.	0.368	64.
1991	0.	0.	97.	97.	1.898	184.	0.334	62.
1992	0.	0.	97.	97.	2.012	195.	0.304	59.
1993	0.	0.	97.	97.	2.133	207.	0.276	57.
1994	0.	0.	97.	97.	2.261	219.	0.251	55.
1995	0.	0.	97.	97.	2.397	232.	0.228	53.
1996	0.	0.	97.	97.	2.540	246.	0.208	51.
1997	0.	0.	97.	97.	2.693	261.	0.189	49.
TOTAL	0.	1539.	2378.	3917.		5421.		3172.

TABLE 4.2.1-3c EXAMPLE -1. DATA USED IN LCC ESTIMATES

DATA USED IN LCC ESTIMATE:

PROGRAM & O&S DATA

N	39	M	20.	KR	20.00
NC	10	TS	336.	KN	87.44
FSTO	0.33	PL	0.95	KT	0.50
CMAX	200.00	TO	8760.	KC	1.00
CMIN	24.00	TR	1440.	KD	0.10
RATE4	43.75	FC	3.	KL	0.06
RATE3	35.00	U	0.05	YRDTE	1980
RATE1	26.90	KI	54.00	TRDTE	0
RATE2	26.00	KIR	128.00	YMANU	1980
RATE5	20.00	KOM	42.00	TMANU	3
				YOAS	1983

MC DEVICE DATA

I	NEW	MEM	MOS	DIG	ECL	FP	NG	NB	NP	DEVQ*	REL	SCRN
1	0.	0.	0.	1.	0.	1.	500.	0.	40.	600.	1.0	1.
2	0.	0.	0.	1.	0.	1.	500.	0.	40.	600.	1.0	1.
3	0.	0.	0.	1.	0.	1.	500.	0.	40.	600.	1.0	1.
4	0.	0.	0.	1.	0.	1.	500.	0.	40.	600.	1.0	1.
5	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
6	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
7	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
8	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
9	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
10	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
11	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
12	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
13	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
14	0.	0.	0.	1.	0.	1.	10.	0.	16.	3000.	1.0	1.
15	0.	1.	0.	0.	0.	1.	0.	1000.	16.	4800.	1.0	1.
16	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
17	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
18	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
19	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
20	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
21	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
22	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
23	0.	0.	0.	0.	0.	1.	19.	0.	16.	300.	1.0	1.
24	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
25	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
26	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
27	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
28	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
29	0.	0.	0.	1.	0.	1.	20.	0.	15.	300.	1.0	1.
30	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
31	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
32	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
33	0.	0.	0.	1.	0.	1.	20.	0.	16.	300.	1.0	1.
34	0.	1.	1.	0.	0.	1.	0.	64000.	16.	6400.	1.0	1.
35	0.	0.	1.	1.	0.	1.	20.	0.	16.	200.	1.0	1.
36	0.	0.	1.	1.	0.	1.	20.	0.	16.	200.	1.0	1.
37	0.	0.	1.	1.	0.	1.	20.	0.	16.	200.	1.0	1.
38	0.	0.	1.	1.	0.	1.	20.	0.	16.	200.	1.0	1.
39	0.	0.	1.	1.	0.	1.	20.	0.	16.	200.	1.0	1.

* TOTAL QUANTITY OF MC DEVICES.

CARD DATA

I	CARD*	NDEV	NMC	QA	QB	QB1	QB2	QCD	NDS	NCB	NRAM	W	CF	KA	KS
1	100.	112.	62.	0.	62.	0.	0.	0.	2500.	0.	8.	0.81	.0000027	1000.	5000.
2	100.	112.	62.	0.	62.	0.	0.	0.	2500.	0.	8.	0.81	.0000027	0.	0.
3	100.	112.	62.	0.	62.	0.	0.	0.	2500.	0.	8.	0.81	.0000027	0.	0.
4	100.	112.	62.	0.	62.	0.	0.	0.	2500.	0.	8.	0.81	.0000027	0.	0.
5	100.	112.	62.	0.	62.	0.	0.	0.	2500.	0.	8.	0.81	.0000027	0.	0.
6	100.	112.	62.	0.	62.	0.	0.	0.	2500.	0.	8.	0.81	.0000027	0.	0.
7	60.	136.	36.	0.	36.	0.	0.	0.	400.	334.	0.	0.70	.0000034	1000.	60000.
8	60.	136.	36.	0.	36.	0.	0.	0.	400.	334.	0.	0.70	.0000034	1000.	60000.
9	60.	136.	36.	0.	36.	0.	0.	0.	400.	334.	0.	0.70	.0000034	1000.	60000.
10	100.	124.	74.	0.	74.	0.	0.	0.	200.	0.	64.	0.99	.0001095	1000.	8000.

* TOTAL QUANTITY OF CARDS.

TABLE 4.2.1-4. QUALITY GRADE IMPACT ON LCC (K$)

COST ELEMENT	QUALITY GRADE			
	B	B-1	B-2	C
Production	1539	1533	1566	1656
Device Procurement	153	147	141	138
Card Assembly	1386	1386	1425	1518
Maintenance & Support	2378	5629	11489	14286
Spares	1684	4245	8860	11057
Support Equipment	198	198	198	198
Inventory Entry	151	151	151	151
Repair Labor	195	585	1275	1575
Repair Materials	150	435	960	1245
Main. Transportation	0	15	45	60
Totals	3917	7162	13055	15942

While the procurement cost increases as the quality grade increases, card assembly costs decrease (because of better yields in the factory) producing overall production costs that decrease as the quality grade increases. The most dramatic changes, however, occur in the Maintenance Support Phase. Over an operating life of 15 years significant cost differences occur as the quality grade of MC devices increases. This difference, of course, is driven by the operating profile (assumed 24 hours/day) the number of operating systems.

The results clearly indicate that the total cost to a system decreases as the quality grades of MC devices increase. However, it should be emphasized that in this example all MC devices quality grades are assumed to be available off-the-shelf. The degree to which they are not available greatly affects the procurement cost.

4.2.2 INHOUSE SCREENING TO B-1 VS QUALIFYING TO B

The affects on LCC of upgrading commercial grade devices (C-level) to a quality grade B-1 by inhouse screening versus the alternative of qualifying the vendor and these devices to a JAN B quality grade is analyzed. The digital logic LSI devices employed in the population of high-density cards defined in example 1 are candidates for this analysis.

Case 1 - Screen Commercial Grade LSI Devices to B-1

With reference to the data sets assembled in example 1, the changes necessary to analyze this problem are as follows:

- B quality level for all non-LSI MC devices
- LSI (i.e., 100 or more gates) are commercial grade - REL = 8.0

- LSI are screened (SCRN = 2)
- Card failure rates (CF) are adjusted per MIL-HDBK-217 (see step 1 in Example 1) so that the LSI devices are B-1. The only cards affected are the digital logic cards (CF = 3.14 X 10^{-6})
- Ratio contribution of LSI MC devices to card failure rate is re-calculated (W=.84)

These changes are made to the input files 02 (DEVICE.DATA) and 03 (CARD.DATA), and the data sets are re-allocated (STEP 3). The LCC model is then executed (STEP 4) and the results of the LCC estimate are provided in Tables 4.2.2-1a and 4.2.2-1b. For this population of cards, therefore, the total LCC impact is $4,197k in constant dollars.

Case 2 - Qualify LSI Devices to JAN B

The B-level quality grade data is provided in Example 1 Table 4.2.1-3c. In this case, the device manufacturers must qualify the LSI commercial devices to JAN B at a cost of approximately $150k per device (refer to Section 3.4 for a discussion on device qualification). For the four LSI device types being upgraded this is a total cost of $600k that must be incurred for qualification. Therefore, the LCC for this case is $4,517k in constant dollars.

For the card population used in the above cases, it turns out that device qualification is a more expensive solution to the problem. However, this result is clearly a function of card population. By increasing the card population, device screening becomes more expensive and eventually overcomes the cost of qualification at approximately double the original device population in this example. This is illustrated in Figure 4.2.2-1 where the points on the curve were obtained by successive runs of the LCC model with changes in card quantities (CARD) and corresponding changes in the MC device population (DEVQ).

4.2.3 CUSTOM LSI VS STANDARD SSI/MSI

The affects on LCC of implementing digital logic cards with custom LSI devices versus standard SSI/MSI devices into a system is analyzed. The custom digital logic LSI devices employed are assumed to be procured at a commercial grade (C-level) and require screening to a B-1 level. The device and card characteristics for these custom cards are given in Tables 4.2.1-1 and 4.2.1-2 of Example 1. The standard SSI/MSI device and card characteristics for this example are given in Tables 4.2.3-1 and 4.2.3-2.

TABLE 4.2.2-1a EXAMPLE -2. MC DEVICE IMPACT ON LCC

MC DEVICE IMPACT ON LCC (THOUSANDS OF DOLLARS)

COST ELEMENT	CONSTANT DOLLARS 5 YEARS	10 YEARS	15 YEARS
RDT&E	0.	0.	0.
PRODUCTION	1848.	1848.	1848.
DEVICE PROCUREMENT	153.	153.	153.
DEVICE SCREEN	315.	315.	315.
CARD ASSEMBLY	1380.	1380.	1380.
OPERATIONS & SUPPORT	1424.	1924.	2424.
SPARES	1050.	1375.	1700.
SUPPORT EQUIPMENT	198.	198.	198.
INVENTORY ENTRY	51.	101.	151.
REPAIR LABOR	65.	130.	195.
REPAIR MATERIALS	60.	120.	180.
MAIN. TRANSPORTATION	0.	0.	0.
TOTAL COST	3272.	3772.	4272.

TABLE 4.2.2-1b EXAMPLE -2. LCC SUMMARY BY FISCAL YEAR

LCC SUMMARY BY FISCAL YEAR (THOUSANDS OF DOLLARS)

FISCAL YEAR	PROGRAM PHASE RDT&E	PROD	O&S	TOTAL DOLLARS	PRICE INDEX	INFLATED DOLLARS	DISC. FACT.	TOTAL COST
1980	0.	616.	0.	616.	1.000	616.	0.954	588.
1981	0.	616.	0.	616.	1.060	653.	0.867	566.
1982	0.	616.	0.	616.	1.124	692.	0.788	545.
1983	0.	0.	1024.	1024.	1.191	1220.	0.717	874.
1984	0.	0.	100.	100.	1.262	126.	0.651	82.
1985	0.	0.	100.	100.	1.338	134.	0.592	79.
1986	0.	0.	100.	100.	1.419	142.	0.538	76.
1987	0.	0.	100.	100.	1.504	150.	0.489	73.
1988	0.	0.	100.	100.	1.594	159.	0.445	71.
1989	0.	0.	100.	100.	1.689	169.	0.405	68.
1990	0.	0.	100.	100.	1.791	179.	0.368	66.
1991	0.	0.	100.	100.	1.898	190.	0.334	64.
1992	0.	0.	100.	100.	2.012	201.	0.304	61.
1993	0.	0.	100.	100.	2.133	213.	0.276	59.
1994	0.	0.	100.	100.	2.261	226.	0.251	57.
1995	0.	0.	100.	100.	2.397	240.	0.228	55.
1996	0.	0.	100.	100.	2.540	254.	0.208	53.
1997	0.	0.	100.	100.	2.693	269.	0.189	51.
TOTAL	0.	1848.	2424.	4272.		5833.		3488.

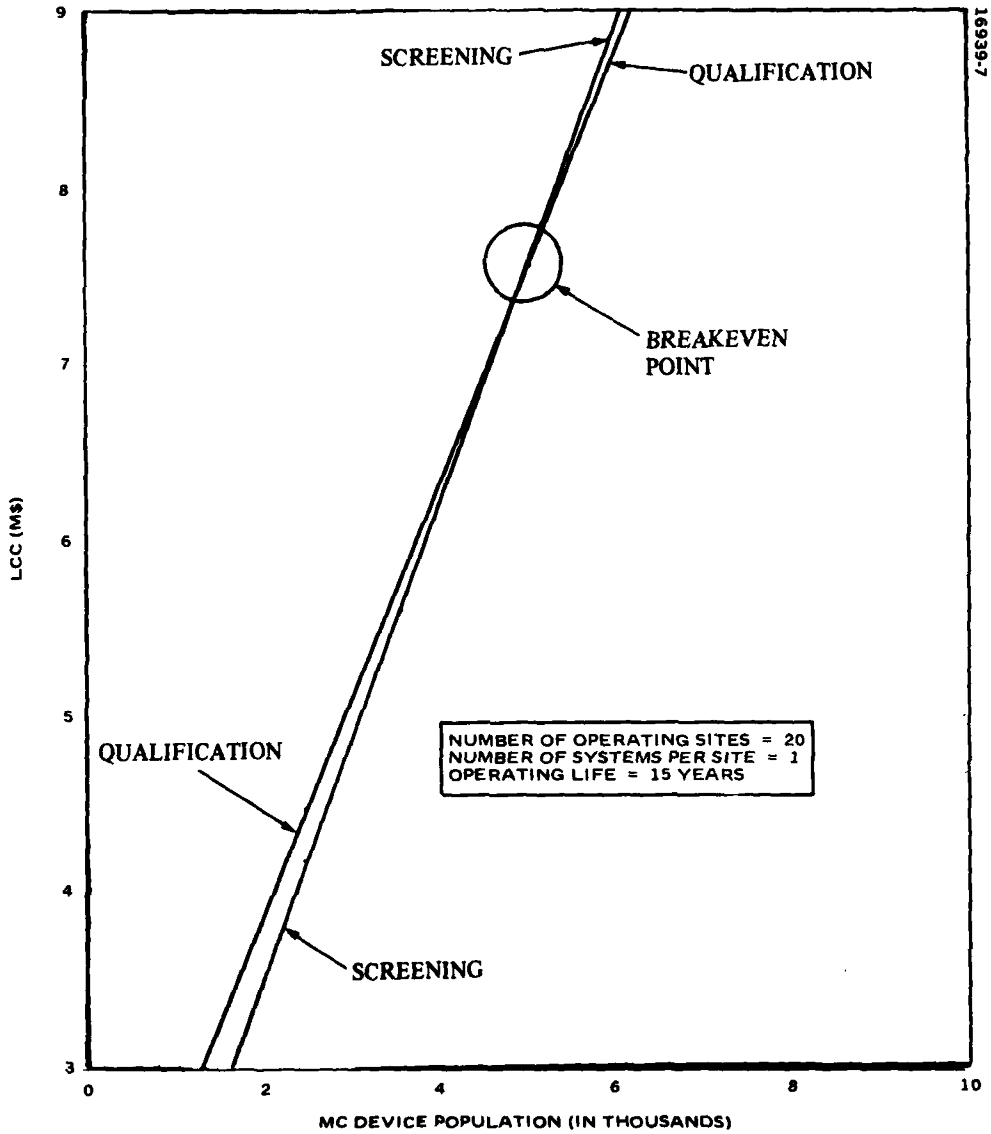

Figure 4.2.2-1. Vendor Qualification vs Inhouse Screening

Case 1 - Implement Digital Logic Functions With Custom LSI Devices

With reference to the data sets in Example 1 (Steps 1 and 2) changes necessary to analyze this problem are as follows:

- RDT&E start (YRDTE) is 1980 with a duration (TRDTE) of 1 year. Production starts (YMANU) in 1981 and Operations and Support starts (YOAS) in 1984.
- B quality level for all non-LSI MC devices.
- LSI devices are commercial grade (REL=8.0), new devices (NEW=1), and are to be screened (SCRN=2).
- The LSI devices are complete custom (FSTD=0) and, with the change to LSI, fault isolation to the card level is assumed (FC=0).
- Card failure rates (CF) are adjusted per MIL-HDBK-217. The only cards affected are the digital logic cards (CF = 3.14×10^{-6}).
- The ratio card contribution of LSI MC devices to the card failure rate is re-calculated W = .84).
- For new cards, support equipment adapter cost (KA) is $2,000 per card type and $10,000 per card type for software development (KS). For all other cards, KA and KS are assumed to be zero.

The changes are made in the input FILE 01 (PROGRAM.DATA), FILE 02 (DEVICE.DATA) and FILE 03 (CARD.DATA). The data sets are re-allocated (Step 3) and the LCC model is executed (Step 4). The results of the model output is given in Tables 4.2.3-3a and b. The LCC estimate for this case is $3,311K (constant dollars).

Case 2 - Implement Digital Logic Cards With Standard SSI/MSI Devices

For this case, the data needed for the digital logic cards is given in Tables 4.2.3-1 and 4.2.3-2. Card and system data is provided in Tables 4.2.3-1 and 4.2.3-2.

The changes to the data sets necessary to analyze this case are as follows:

- N=35, NC=49 and FC=3 for FILE 01
- Replace the input data for the "custom" digital logic cards with the input data for the "standard" digital logic cards in FILES 02 and 03, recalculating the parameter values from Tables 4.2.3-1, -2 as described previously.
- B quality level for all MC devices (REL=1).

TABLE 4.2.3-1. CARD DATA FOR EXAMPLE -3 (CASE 2)

DEVICE DESCRIPTION	DEVICE TYPE EACH CATEGORY	DEVICE QTY PER TYPE	TOTAL DEVICES PER CARD	TOTAL GATES PER CARD (NG)	TOTAL FAILURE RATE PER CARD (CR)
SSI/MSI Digital Logics @					
16 gates/device	7	4	28	448	.448
10 gates/device	3	4	12	120	.192
6 gates/device	1	20	20	120	.320
Active and Passive devices	-	50	50	--	.500
			NDEV=110	NDG=688	1.460

TABLE 4.2.3-2. SYSTEM DATA FOR EXAMPLE -3 (CASE 2)

CARD DESCRIPTION	NUMBER OF CARD TYPES	QTY OF CARDS PER TYPE (CARD)	TOTAL CARDS PER SYSTEM	TOTAL FOR 20 SITES
Digital Logic (SSI/MSI)	45	50	112	2,250

- None of the devices are to be screened (SCRN=1).
- Software and card adapter development costs for the cards is assumed to have been developed (i.e., KA=KS=0).

The results of the model output for this case are given in Tables 4.2.3-4a and b. The LCC estimate for this case is $6,480 (constant dollars).

Therefore, for the card and device population used in the above cases, the development and implementation of custom LSI devices is less expensive in LCC than standard SSI/MSI devices. However, the most significant determining factor for the outcome of this example tradeoff is the difference in the number of cards necessary for LSI implementation versus those required for the standard SSI/MSI implementation. The total number of digital logic cards using LSI is 600 and the number of cards using SSI/MSI is 2,250. This factor alone has a tremendous impact on the card assembly cost and on maintenance support costs. Obviously, an implementation leading to a smaller card difference could swing this tradeoff the other way.

TABLE 4.2.3-3a EXAMPLE -3. MC DEVICE IMPACT ON LCC (CASE 1)

MC DEVICE IMPACT ON LCC (THOUSANDS OF DOLLARS)

COST ELEMENT	CONSTANT DOLLARS 5 YEARS	10 YEARS	15 YEARS
RDT&E	406.	406.	406.
PRODUCTION	1881.	1881.	1881.
DEVICE PROCUREMENT	153.	153.	153.
DEVICE SCREEN	348.	348.	348.
CARD ASSEMBLY	1380.	1380.	1380.
OPERATIONS & SUPPORT	614.	819.	1024.
SPARES	416.	496.	576.
SUPPORT EQUIPTMENT	72.	72.	72.
INVENTORY ENTRY	51.	101.	151.
REPAIR LABOR	15.	30.	45.
REPAIR MATERIALS	60.	120.	180.
MAIN. TRANSPORTATION	0.	0.	0.
TOTAL COST	2901.	3106.	3311.

TABLE 4.2.3-3b EXAMPLE -3. LCC SUMMARY BY FISCAL YEAR (CASE 1)

LCC SUMMARY BY FISCAL YEAR (THOUSANDS OF DOLLARS)

FISCAL YEAR	PROGRAM PHASE RDT&E	PROD	O&S	TOTAL DOLLARS	PRICE INDEX	INFLATED DOLLARS	DISC. FACT.	TOTAL COST
1980	406.	0.	0.	406.	1.000	406.	0.954	387.
1981	0.	627.	0.	627.	1.060	665.	0.867	577.
1982	0.	627.	0.	627.	1.124	704.	0.788	555.
1983	0.	627.	0.	627.	1.191	747.	0.717	535.
1984	0.	0.	450.	450.	1.262	568.	0.651	370.
1985	0.	0.	41.	41.	1.338	55.	0.592	33.
1986	0.	0.	41.	41.	1.419	58.	0.538	31.
1987	0.	0.	41.	41.	1.504	62.	0.489	30.
1988	0.	0.	41.	41.	1.594	65.	0.443	29.
1989	0.	0.	41.	41.	1.689	69.	0.405	28.
1990	0.	0.	41.	41.	1.791	73.	0.368	27.
1991	0.	0.	41.	41.	1.898	78.	0.334	26.
1992	0.	0.	41.	41.	2.012	83.	0.304	25.
1993	0.	0.	41.	41.	2.133	87.	0.276	24.
1994	0.	0.	41.	41.	2.261	93.	0.251	23.
1995	0.	0.	41.	41.	2.397	98.	0.228	22.
1996	0.	0.	41.	41.	2.540	104.	0.208	22.
1997	0.	0.	41.	41.	2.693	110.	0.189	21.
1998	0.	0.	41.	41.	2.854	117.	0.172	20.
TOTAL	406.	1881.	1024.	3311.		4242.		2785.

TABLE 4.2.3-4a EXAMPLE -3. MC DEVICE IMPACT ON LCC (CASE 2)

MC DEVICE IMPACT ON LCC (THOUSANDS OF DOLLARS)

COST ELEMENT	CONSTANT DOLLARS 5 YEARS	10 YEARS	15 YEARS
RDT&E	0.	0.	0.
PRODUCTION	3030.	3030.	3030.
DEVICE PROCUREMENT	267.	267.	267.
DEVICE SCREEN	0.	0.	0.
CARD ASSEMBLY	2763.	2763.	2763.
OPERATIONS & SUPPORT	2110.	2780.	3450.
SPARES	1762.	2087.	2412.
SUPPORT EQUIPMENT	0.	0.	0.
INVENTORY ENTRY	243.	483.	723.
REPAIR LABOR	70.	140.	210.
REPAIR MATERIALS	35.	70.	105.
MAIN. TRANSPORTATION	0.	0.	0.
TOTAL COST	5140.	5810.	6480.

TABLE 4.2.3-4b EXAMPLE -3. LCC SUMMARY BY FISCAL YEAR (CASE 2)

LCC SUMMARY BY FISCAL YEAR (THOUSANDS OF DOLLARS)

FISCAL YEAR	PROGRAM PHASE RDT&E	PROD	O&S	TOTAL DOLLARS	PRICE INDEX	INFLATED DOLLARS	DISC. FACT.	TOTAL COST
1980	0.	1010.	0.	1010.	1.000	1010.	0.954	963.
1981	0.	1010.	0.	1010.	1.060	1071.	0.867	929.
1982	0.	1010.	0.	1010.	1.124	1135.	0.788	895.
1983	0.	0.	1574.	1574.	1.191	1875.	0.717	1344.
1984	0.	0.	134.	134.	1.262	169.	0.651	110.
1985	0.	0.	134.	134.	1.338	179.	0.592	106.
1986	0.	0.	134.	134.	1.419	190.	0.538	102.
1987	0.	0.	134.	134.	1.504	201.	0.489	98.
1988	0.	0.	134.	134.	1.594	214.	0.445	95.
1989	0.	0.	134.	134.	1.689	226.	0.405	91.
1990	0.	0.	134.	134.	1.791	240.	0.368	88.
1991	0.	0.	134.	134.	1.898	254.	0.334	85.
1992	0.	0.	134.	134.	2.012	270.	0.304	82.
1993	0.	0.	134.	134.	2.133	286.	0.276	79.
1994	0.	0.	134.	134.	2.261	303.	0.251	76.
1995	0.	0.	134.	134.	2.397	321.	0.228	73.
1996	0.	0.	134.	134.	2.540	340.	0.208	71.
1997	0.	0.	134.	134.	2.693	361.	0.189	68.
TOTAL	0.	3030.	3450.	6480.		8643.		5355.

Section 5.0

CONCLUSIONS AND RECOMMENDATIONS

A method of assessing the life cycle cost (LCC) impact of microcircuits (MC) on military electronic systems has been developed which uses parametric cost estimating relationships (CER's). The CER's have been combined into a comprehensive computerized LCC model which has been exercised to determine the general effects of MC factors on LCC. These general effects are summarized in Section 1.0 together with the underlying assumptions and ground rules used in the development of the CER's.

MC factors are categorized (see Table 2.3-1) with respect to technology, function, packaging, complexity, and quality/reliability. The factors that were cost sensitive were found to have effects which extend over the entire operational life cycle of a system. For example, device technology (i.e., linear, digital, bipolar MOS, ECL, etc) has an effect on device purchase price which determines the bulk of the circuit card assembly (CCA) material and cost and, therefore, effects the cost of spares needed for maintenance support. Similarly, MC device complexity (i.e., number of gates or memory bits) can have an effect on design partitioning and, therefore, on the cost, numbers and types of CCA's employed in the system. Device complexity can, therefore, result in a direct impact on system spares, and on inventory entry and supply management.

Although the LCC model structure is general, the CER's used in the model should be updated periodically to reflect significant changes in MC technology. Specifically, changes with regard to availability of new technologies (i.e., ECL, IIL, etc) at the higher complexity levels. As more data becomes available on these devices, the appropriate CER's should be expanded. As stated earlier in this report, the CER's are not generally applicable to hybrid technology. Because of the fabrication techniques unique to hybrids, it is recommended that separate CER's be developed for these devices. An independent study of hybrid fabrication techniques and costs was conducted by Hughes[6] and could be used as a starting point for this development.

Finally, those costs which are insensitive to differences in MC characteristics have not been included in the CER's. The LCC model should, therefore, be used only for <u>comparative</u> analyses and not for estimating <u>total</u> cost.

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Appendix A

Regression Analysis Results

Each of the regression runs in this appendix provide the following information:

a) The data sets necessary to execute the regression analysis. The data sets variable names and format codes are provided at the top of each data set.

b) A list of the means and standard deviations for the variables considered in the regression analysis.

c) A correlation matrix for each of the independent variables showing the individual correlations with the dependent variables.

d) The stepwise regression equations for the CER. At each step the multiple R, the standard error of estimate, and an Analysis-of-variance table is provided. For the independent variables in the equation regression coefficients, standard error, and F-to-remove values are given. For the variables not in the equation, partial correlations, Tolerances and F-to-enter values are given. (Section 2.2.)

e) A summary table of the regression analysis. Included in this table is a summary of the regression steps, the step at which variables were entered into the equation, the multiple R and R^2 values, the increase in the R^2 value, the F-value to enter or remove, and the number of independent variables included in the CER.

f) A list of residuals and plots of the residuals against the observations and against the computed values of the dependent variable.

REGRESSION ANALYSIS RESULTS FOR DEVICE PROCUREMENT (PCER1)

```
LABELS   1S         2LS        3L         4H         5MEM       6LNPUR
LABELS   7DIG       8LIN       9OTHER     10ECL      11CMOS     12MOS
LABELS  13NG        14HERMET  15FP        16REL      17NB       1816/13
LABELS  1916/17     56PURCH
(5F2.0,12X,F6.4,6F2.0,F3.0,2F2.0,F5.1,F5.0/F8.4,F7.5)
 0 0 0 0 0 54/74193    - 1997 1 0 1 0 0 0 48 1 0   80     0
    1667 0
 0 1 0 0 0 54/74LS113    3365 1 0 0 0 0 0 16 1 1   10     0
    0625 0
 0 1 0 0 0 54/74LS257 - 0222 1 0 0 0 0 0 15 1 0   30     0
    2000 0
 0 0 0 1 0 54/74H00    - 6733 1 0 0 0 0 0  4 1 0   65     0
   16250 0
 0 0 0 1 0 54/74H72    - 2319 1 0 0 0 0 0  8 1 1   10     0
    1250 0
 0 0 0 1 0 54/74H101     3920 1 0 0 0 0 0 10 1 1   10     0
    1000 0
 0 0 0 0 0 9093          3001 1 0 1 0 0 0 16 1 0   30     0
    1875 0
 0 0 0 0 0 9614          3436 1 0 1 0 0 0  6 1 0   30     0
    5000 0
 0 0 0 0 0 9311          7324 1 0 1 0 0 0 25 1 1   80     0
    3200 0
 0 0 0 0 0 LM101A        0276 0 1 1 0 0 0 21 1 0   65     0
    3095 0
 0 0 0 0 0 711           2271 0 1 1 0 0 0  4 1 1   30     0
    7500 0
 0 0 0 0 0 723           9933 0 1 1 0 0 0  5 1 0   10     0
    2000 0
 0 0 0 0 0 7815          6663 0 1 1 0 0 0  4 1 1   30     0
    7500 0
 0 0 0 0 0 9615        - 1985 0 1 1 0 0 0  9 1 0   80     0
    8889 0
 0 0 0 0 0 9301          4606 1 0 1 0 0 0 18 1 1   65     0
    3611 0
 0 0 0 0 0 710         - 3638 0 1 1 0 0 0  2 1 1   65     0
   32500 0
 0 0 0 0 0 54/74365    -13665 1 0 1 0 0 0  7 0 0  350     0
   50000 0
 0 0 0 0 0 LM106       -12040 0 1 1 0 0 0  3 0 0  350     0
  116667 0
 0 0 0 0 0 54/7492     -14397 1 0 1 0 0 0 26 0 0  350     0
   13462 0
 1 0 0 0 0 54/74S03    -13744 1 0 0 0 0 0  4 1 0  175     0
   43750 0
 0 0 0 0 0 4001        - 5534 1 0 0 0 1 0  4 1 0   65     0
   16250 0
 0 0 0 0 0 4025         19459 1 0 0 0 1 0  3 1 1   10     0
    3333 0
 0 0 0 0 0 4075        -18972 1 0 0 0 1 0  3 1 0  175     0
   58333 0
 0 0 0 0 0 10101        10818 1 0 0 1 0 0  4 1 0   80     0
   20000 0
 0 0 0 0 0 10104        21401 1 0 0 1 0 0  4 1 1   30     0
    7500 0
 0 0 0 0 0 10106       - 3567 1 0 0 1 0 0  3 1 0  175     0
   58333 0
 1 0 0 0 1 82S16        14540 0 0 0 0 0 0  0 1 1   65   256
   0      02539    3938462
 1 0 0 0 1 82S126       22513 0 0 0 0 0 0  0 1 0   10  1024
   0      00098 1024
 0 1 0 0 1 27LS00        5878 0 0 0 0 0 0  0 0 0  350   256
   0      18672     731429
 1 0 0 0 1 82S184       34012 0 0 0 0 0 0  0 1 1   80  8192
   0      00098 1024
 0 0 1 0 1 93L425       28034 0 0 0 0 0 0  0 1 1   65  1024
   0      00635  15753844
 0 1 0 0 1 74LS207      24204 0 0 0 0 0 0  0 0 0  350  1024
   0      03418    2925714
```

```
1 0 0 0 1 74S188      - 5961 0 0 0 0 0 0  0 1 0   80  256
 0      03125    32
1 0 0 0 1 74S476       16409 0 0 0 0 0 0  0 1 0  175 4096
 0      00427  23405714
1 0 0 0 1 82S191       29857 0 0 0 0 0 0  0 1 0   8016384
 0      00049 2048
1 0 0 0 1 54S89        14351 0 0 0 0 0 0  0 1 1   65  256
 0      02539   3938462
1 0 0 0 1 82S09        34275 0 0 0 0 0 0  0 1 1   30  576
 0      00521  192
0 1 0 0 1 74LS314      18795 0 0 0 0 0 0  0 1 0  175 1024
 0      01709   5851429
1 0 0 0 1 82S23        11474 0 0 0 0 0 0  0 1 1   30  256
 0      01172   8533333
1 0 0 0 1 74S477       16409 0 0 0 0 0 0  0 1 0  175 4096
 0      00427  23405714
1 0 0 0 1 74S387        1823 0 0 0 0 0 0  0 0 0  350 1024
 0      03418   2925714
0 0 0 0 1 93448        25533 0 0 1 0 0 0  0 1 1   65 4096
 0      00159  63015385
0 0 0 1 0 54/74H50    -10642 1 0 0 0 0 0  6 1 0   80    0
 13333 0
0 0 0 0 0 78M12         5247 0 1 1 0 0 0  4 1 1   30    0
  7500 0
0 0 0 0 0 10016        22246 1 0 0 1 0 0 59 1 1   30    0
  0508 0
0 0 0 0 0 741A          9933 0 1 1 0 0 0  6 1 1   65    0
 10833 0
0 0 0 0 0 555           3485 0 1 1 0 0 0  6 1 0   30    0
  5000 0
0 0 0 0 0 9614          4055 1 0 1 0 0 0  6 1 1   80    0
 13333 0
0 0 0 0 1 4050        - 7985 0 0 0 0 0 1  0 1 0   30    0
 0     0
0 0 0 0 0 711          22354 0 1 1 0 0 0  4 1 0   10    0
  25   0
0 0 0 1 0 54/74H04    - 0030 1 0 0 0 0 0  6 1 0   10    0
  1667 0
0 0 0 1 0 54/74H103     5008 1 0 0 0 0 0 12 1 0   10    0
  0833 0
0 1 0 0 0 54/74LS00   - 8989 1 0 0 0 0 0  4 1 0   65    0
 16250 0
0 0 0 0 0 9601        - 7700 1 0 0 0 0 0  8 1 0   80    0
 1     0
1 0 0 0 1 82S129        8671 0 0 1 0 0 0  0 1 0   80  256
 0      03125    32
1 0 0 0 1 82S10        30564 0 0 1 0 0 0  0 1 1   30  256
 0      01172   8533333
0 0 0 1 0 54/74H40    - 3467 1 0 0 0 0 0  2 1 1   30    0
 15    0
0 1 0 0 0 54/74LS00   - 8989 1 0 0 0 0 0  4 1 1   30    0
  75   0
0 1 0 0 0 54/74LS166    5008 1 0 0 0 0 0 68 1 0   65    0
  0956 0
0 0 0 0 0 10116        17047 1 0 0 1 0 0  4 1 0   30    0
  75   0
0 0 0 0 0 10124        20541 1 0 0 1 0 0  4 1 1   30    0
  75   0
0 0 0 0 0 10125         0583 1 0 0 1 0 0  4 0 0  350    0
 875   0
0 0 0 0 0 10109        16390 1 0 0 1 0 0  2 1 1   80    0
 4     0
0 0 0 0 0 10131        14469 1 0 0 1 0 0 10 1 0   80    0
  8    0
0 0 0 0 0 4011          3646 1 0 0 0 1 0  4 1 1   30    0
  75   0
0 0 0 0 0 4066         13900 0 1 0 0 1 0  4 1 1   65    0
 16250 0
```

```
0 0 0 0 0 4555      - 7133 0 1 0 0 1 0 13 1 0  175   0
  13462 0
0 0 0 0 0 40192     - 4943 1 0 0 0 1 0 47 0 0  350   0
   7447 0
0 0 0 0 0 4040      - 2984 1 0 0 0 1 0 29 1 0   80   0
   2759 0
```

VARIABLE		MEAN	STANDARD DEVIATION
S	1	0.18841	0.39390
LS	2	0.26087	1.23255
L	3	0.01449	0.12039
H	4	0.10145	0.30413
MEM	5	0.26087	0.44233
LNPUR	6	0.62332	1.27848
DIG	7	0.53623	0.50234
LIN	8	0.18841	0.39390
OTHER	9	0.31884	0.46944
ECL	10	0.13043	0.33925
CMOS	11	0.11594	0.32250
MOS	12	0.01449	0.12039
NG	13	8.52174	13.59453
HERMET	14	0.83406	0.32250
FP	15	0.40580	0.49464
REL	16	9.59420	10.29603
NB	17	642.78247	2311.72314
16/13	18	1.14307	2.08363
16/17	19	0.00628	0.02376
	20	86.68942	305.97314
	21	254.75362	779.74268
	22	1.55072	6.77264
	23	1.36232	7.22123
	24	1.37681	5.23730
	25	1.28261	4.91955
	26	0.05797	0.48154
	27	520.34766	2275.78467
	28	7.26087	12.70784
	29	5.53623	4.91868
	30	0.17391	0.38181
	31	0.01449	0.12039
	32	0.0	0.0
	33	1.55797	4.05797
	34	0.18841	0.39390
	35	0.08696	0.28384
	36	0.04348	0.20542
	37	0.07246	0.26115
	38	0.0	0.0
	39	6.63043	42.41353
	40	0.08696	0.28383
	41	0.02899	0.16899
	42	1.55072	8.55006
	43	181.79709	1241.08350
	44	0.01449	0.12039
	45	0.0	0.0
	46	0.0	0.0
	47	0.09420	0.78251
	48	0.01449	0.12039
	49	0.01449	0.12039
	50	0.0	0.0
	51	14.84058	123.27504
	52	2.80435	6.95374
	53	0.23188	0.42513
	54	627.94189	2312.52588
	55	0.11594	0.32250
	56	4.23464	6.38981

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	7	8	9	10
1	1.000	-0.103	-0.058	-0.162		-0.444	-0.232	-0.171	-0.187
2		1.000	-0.026	-0.072		-0.110	-0.103	-0.146	-0.083
3			1.000	-0.041		-0.130	-0.058	-0.083	-0.047
4				1.00		0.312	-0.162	-0.230	-0.130
5						-0.639	-0.286	-0.194	-0.230
6						-0.397	-0.093	-0.092	0.216
7						1.000	-0.518	-0.237	0.360
8							1.000	0.545	-0.187
9								1.000	-0.265
10									1.000

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19	20
1	-0.174	-0.058	-0.293	0.174	0.055	-0.062	0.445	-0.188	0.112	0.481
2	-0.077	-0.026	-0.041	-0.367	-0.128	0.330	0.005	-0.102	0.234	-0.046
3	-0.044	-0.015	-0.077	0.044	0.147	-0.037	0.020	-0.067	0.000	0.028
4	-0.122	-0.041	-0.041	0.122	0.016	-0.214	-0.394	-0.071	-0.089	-0.096
5	-0.215	0.204	-0.375	0.009	0.047	0.067	0.457	-0.328	0.400	0.477
6	-0.187	-0.136	-0.175	0.223	0.383	-0.279	0.432	-0.432	0.074	0.463
7	0.155	-0.130	0.404	0.026	-0.060	-0.063	-0.301	0.186	-0.286	-0.307
8	0.037	-0.058	-0.071	0.059	0.055	-0.088	-0.135	0.152	-0.128	-0.138
9	-0.248	-0.083	0.075	-0.044	0.068	-0.032	-0.129	0.067	-0.123	-0.119
10	-0.140	-0.047	0.055	0.006	0.030	0.009	-0.108	0.279	-0.103	-0.111
11	1.000	-0.044	0.130	-0.010	-0.023	0.081	-0.101	0.074	-0.096	-0.103
12		1.000	-0.077	0.044	-0.100	-0.078	-0.034	-0.067	-0.032	-0.035
13			1.000	-0.063	-0.108	0.032	-0.177	-0.124	-0.158	-0.180
14				1.000	0.299	-0.900	0.056	-0.402	-0.393	0.094
15					1.000	-0.418	-0.040	-0.100	-0.109	-0.017
16						1.000	0.036	0.487	0.373	-0.061
17							1.000	-0.155	-0.011	0.917
18								1.000	-0.147	-0.158
19									1.000	-0.039
20										1.000

VARIABLE NUMBER	21	22	23	24	25	26	27	28	29	30
1	-0.158	-0.111	-0.092	-0.128	-0.127	0.252	0.478	-0.266	0.270	0.952
2	0.003	-0.049	-0.041	-0.056	-0.056	-0.026	-0.049	-0.022	-0.151	-0.098
3	-0.040	-0.028	-0.023	-0.032	-0.032	-0.015	-0.028	-0.070	0.024	-0.056
4	-0.086	-0.077	-0.064	-0.089	-0.088	-0.041	-0.077	-0.011	-0.170	-0.154
5	-0.196	-0.137	-0.113	-0.157	-0.156	-0.072	0.388	-0.342	0.161	0.772
6	-0.040	-0.175	0.187	-0.255	-0.004	-0.191	0.374	-0.071	-0.073	0.459
7	0.273	0.141	0.177	0.112	0.244	0.113	-0.248	0.346	-0.070	-0.493
8	-0.116	-0.017	-0.092	0.043	-0.127	-0.058	-0.111	-0.036	-0.049	-0.221
9	-0.024	-0.158	-0.130	-0.181	-0.180	-0.083	-0.151	0.060	-0.167	-0.150
10	0.077	-0.089	0.491	-0.103	0.678	-0.047	-0.089	0.084	0.032	-0.178
11	0.073	0.637	-0.069	0.731	-0.095	-0.044	-0.083	0.007	0.146	-0.166
12	-0.040	-0.028	-0.023	-0.032	-0.032	-0.015	-0.028	-0.070	-0.063	-0.056
13	0.942	0.379	0.430	0.292	-0.049	-0.041	-0.145	0.831	-0.078	-0.290
14	-0.054	-0.233	0.044	-0.209	-0.229	0.044	0.083	0.208	0.411	0.166
15	-0.079	-0.142	0.127	-0.159	-0.114	-0.100	-0.062	-0.033	-0.187	0.088
16	0.037	0.253	-0.073	0.296	0.264	0.094	0.035	-0.214	0.028	-0.094
17	-0.092	-0.065	-0.053	-0.074	-0.074	-0.034	0.972	-0.161	0.203	0.470
18	-0.128	-0.028	-0.019	0.093	0.529	0.189	-0.127	-0.174	0.098	-0.254
19	-0.088	-0.061	-0.051	-0.070	-0.070	-0.032	-0.037	-0.153	-0.122	0.126
20	-0.094	-0.066	-0.054	-0.076	-0.075	-0.035	0.837	-0.164	0.087	0.507
21	1.000	0.288	0.477	0.228	-0.039	-0.037	-0.076	0.860	-0.046	-0.151
22		1.000	-0.044	0.861	-0.061	-0.028	-0.053	0.051	-0.006	-0.106
23			1.000	-0.050	0.171	-0.023	-0.044	0.477	-0.053	-0.087
24				1.000	-0.070	-0.032	-0.061	-0.024	0.140	-0.122
25					1.000	-0.032	-0.060	-0.059	0.027	-0.121
26						1.000	-0.028	-0.031	0.297	-0.056
27							1.000	-0.133	0.201	0.502
28								1.000	0.030	-0.264
29									1.000	0.185
30										1.000

VARIABLE NUMBER	31	32	33	34	35	36	37	38	39	40
1	0.252	0.0	0.803	1.000	0.641	-0.103	-0.135	0.0	-0.076	-0.149
2	-0.026	0.0	-0.032	-0.103	-0.066	0.129	0.159	0.0	0.931	0.186
3	-0.015	0.0	-0.047	-0.058	-0.037	-0.026	-0.034	0.0	-0.019	-0.037
4	-0.041	0.0	-0.130	-0.162	-0.104	-0.072	-0.094	0.0	-0.053	-0.104
5	-0.072	0.0	0.508	0.727	0.519	0.359	-0.164	0.0	-0.025	-0.066
6	-0.191	0.0	0.180	0.336	0.413	0.169	-0.151	0.0	-0.024	-0.115
7	0.113	0.0	-0.290	-0.444	-0.332	-0.229	0.260	0.0	-0.156	0.184
8	-0.058	0.0	-0.186	-0.232	-0.149	-0.103	-0.135	0.0	-0.076	-0.149
9	-0.083	0.0	-0.180	-0.171	-0.101	-0.146	-0.191	0.0	-0.108	-0.211
10	-0.047	0.0	-0.150	-0.187	-0.120	-0.083	-0.108	0.0	-0.061	-0.120
11	-0.044	0.0	-0.140	-0.174	-0.112	-0.077	-0.101	0.0	-0.057	-0.112
12	-0.015	0.0	-0.047	-0.058	-0.037	-0.026	-0.034	0.0	-0.019	-0.037
13	-0.041	0.0	-0.226	-0.293	-0.195	-0.135	0.267	0.0	-0.086	0.213
14	0.044	0.0	0.140	0.174	0.112	-0.367	0.101	0.0	-0.395	0.112
15	-0.100	0.0	-0.100	0.055	0.373	-0.176	-0.003	0.0	-0.127	-0.046
16	0.094	0.0	0.090	-0.062	-0.139	0.408	-0.153	0.0	0.361	-0.101
17	-0.034	0.0	0.443	0.445	0.133	0.012	-0.078	0.0	0.019	-0.063
18	0.159	0.0	-0.081	-0.188	-0.171	-0.118	-0.081	0.0	-0.085	-0.103

19	-0.022	0.0	0.062	0.112	0.093	0.660	-0.074	0.0	0.250	-0.045
20	-0.035	0.0	0.315	0.431	0.160	-0.039	-0.080	0.0	-0.031	-0.078
21	-0.037	0.0	-0.126	-0.158	-0.102	-0.079	0.279	0.0	-0.038	0.240
22	-0.008	0.0	-0.029	-0.111	-0.071	-0.049	-0.054	0.0	-0.036	-0.071
23	-0.023	0.0	-0.073	-0.092	-0.059	-0.041	-0.053	0.0	-0.030	-0.059
24	-0.032	0.0	-0.102	-0.128	-0.082	-0.056	-0.074	0.0	-0.042	-0.082
25	-0.032	0.0	-0.102	-0.127	-0.081	-0.056	-0.073	0.0	-0.041	-0.081
26	1.000	0.0	0.430	0.252	-0.037	-0.026	-0.034	0.0	-0.019	-0.037
27	-0.020	0.0	0.471	0.478	0.152	-0.049	-0.064	0.0	-0.036	-0.071
28	-0.031	0.0	-0.203	-0.266	-0.173	-0.123	0.313	0.0	-0.076	0.259
29	0.297	0.0	0.510	0.270	-0.034	0.013	-0.088	0.0	-0.150	0.045
30	-0.056	0.0	0.677	0.952	0.573	-0.098	-0.128	0.0	-0.072	-0.142
31	1.000	0.0	0.460	0.252	-0.037	-0.026	-0.034	0.0	-0.019	-0.037
32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33			1.000	0.803	0.264	-0.082	-0.108	0.0	-0.061	-0.119
34				1.000	0.641	-0.103	-0.135	0.0	-0.076	-0.149
35					1.000	-0.066	-0.086	0.0	-0.049	-0.095
36						1.000	-0.060	0.0	0.114	0.186
37							1.000	0.0	-0.017	0.906
38								0.0	0.0	0.0
39									1.000	-0.003
40										1.000

VARIABLE NUMBER	41	42	43	44	45	46	47	48	49	50
1	-0.083	-0.088	-0.071	-0.058	0.0	0.0	-0.058	-0.058	-0.058	0.0
2	0.104	0.110	0.975	-0.026	0.0	0.0	-0.026	-0.026	-0.026	0.0
3	-0.021	-0.022	-0.018	1.000	0.0	0.0	1.000	1.000	1.000	0.0
4	-0.053	-0.061	-0.050	-0.041	0.0	0.0	-0.041	-0.041	-0.041	0.0
5	-0.103	-0.109	-0.026	0.204	0.0	0.0	0.204	0.204	0.204	0.0
6	-0.123	-0.047	-0.013	0.208	0.0	0.0	0.208	0.208	0.208	0.0
7	0.161	0.170	-0.159	-0.130	0.0	0.0	-0.130	-0.130	-0.130	0.0
8	-0.083	-0.028	-0.071	-0.058	0.0	0.0	-0.058	-0.058	-0.058	0.0
9	-0.113	-0.125	-0.101	-0.083	0.0	0.0	-0.083	-0.083	-0.083	0.0
10	-0.057	-0.071	-0.057	-0.047	0.0	0.0	-0.047	-0.047	-0.047	0.0
11	-0.063	-0.066	-0.053	-0.044	0.0	0.0	-0.044	-0.044	-0.044	0.0
12	-0.021	-0.022	-0.018	-0.015	0.0	0.0	-0.015	-0.015	-0.015	0.0
13	0.019	0.535	-0.093	-0.077	0.0	0.0	-0.077	-0.077	-0.077	0.0
14	0.063	0.066	-0.370	0.044	0.0	0.0	0.044	0.044	0.044	0.0
15	0.209	-0.031	-0.122	0.147	0.0	0.0	0.147	0.147	0.147	0.0
16	-0.128	-0.061	0.346	-0.037	0.0	0.0	-0.037	-0.037	-0.037	0.0
17	-0.048	-0.051	0.024	0.020	0.0	0.0	0.020	0.020	0.020	0.0
18	-0.062	-0.084	-0.082	-0.067	0.0	0.0	-0.067	-0.067	-0.067	0.0
19	-0.046	-0.049	0.185	0.000	0.0	0.0	0.000	0.000	0.000	0.0
20	-0.049	-0.052	-0.027	0.028	0.0	0.0	0.028	0.028	0.028	0.0
21	-0.027	0.650	-0.049	-0.040	0.0	0.0	-0.040	-0.040	-0.040	0.0
22	-0.040	-0.042	-0.034	-0.028	0.0	0.0	-0.028	-0.028	-0.028	0.0
23	-0.033	-0.035	-0.023	-0.023	0.0	0.0	-0.023	-0.023	-0.023	0.0
24	-0.046	-0.043	-0.039	-0.032	0.0	0.0	-0.032	-0.032	-0.032	0.0
25	-0.045	-0.048	-0.039	-0.032	0.0	0.0	-0.032	-0.032	-0.032	0.0
26	-0.021	-0.022	-0.018	-0.015	0.0	0.0	-0.015	-0.015	-0.015	0.0
27	-0.040	-0.042	-0.034	-0.028	0.0	0.0	-0.028	-0.028	-0.028	0.0
28	0.023	0.590	-0.085	-0.070	0.0	0.0	-0.070	-0.070	-0.070	0.0
29	-0.125	-0.018	-0.124	0.024	0.0	0.0	0.024	0.024	0.024	0.0
30	-0.079	-0.084	-0.068	-0.056	0.0	0.0	-0.056	-0.056	-0.056	0.0
31	-0.021	-0.022	-0.018	-0.015	0.0	0.0	-0.015	-0.015	-0.015	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	-0.067	-0.071	-0.057	-0.047	0.0	0.0	-0.047	-0.047	-0.047	0.0
34	-0.083	-0.088	-0.071	-0.058	0.0	0.0	-0.058	-0.058	-0.058	0.0
35	-0.053	-0.056	-0.046	-0.037	0.0	0.0	-0.037	-0.037	-0.037	0.0
36	-0.037	-0.039	0.101	-0.026	0.0	0.0	-0.026	-0.026	-0.026	0.0
37	0.618	0.654	-0.041	-0.034	0.0	0.0	-0.034	-0.034	-0.034	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	-0.019	-0.007	0.996	-0.019	0.0	0.0	-0.019	-0.019	-0.019	0.0
40	0.560	0.592	-0.003	-0.037	0.0	0.0	-0.037	-0.037	-0.037	0.0
41	1.000	0.172	-0.025	-0.021	0.0	0.0	-0.021	-0.021	-0.021	0.0
42		1.000	-0.027	-0.022	0.0	0.0	-0.022	-0.022	-0.022	0.0
43			1.000	-0.018	0.0	0.0	-0.018	-0.018	-0.018	0.0
44				1.000	0.0	0.0	1.000	1.000	1.000	0.0
45					0.0	0.0	0.0	0.0	0.0	0.0
46						0.0	0.0	0.0	0.0	0.0
47							1.000	1.000	1.000	0.0
48								1.000	1.000	0.0
49									1.000	0.0
50										0.0

VARIABLE NUMBER	51	52	53	54	55	56
1	-0.058	0.287	0.789	0.448	0.520	0.476
2	-0.026	0.064	-0.089	-0.046	-0.077	-0.074
3	1.000	0.065	0.221	0.021	0.335	0.234
4	-0.041	-0.137	-0.165	-0.092	-0.122	-0.175
5	0.204	0.684	0.925	0.460	0.610	0.569
6	0.203	0.338	0.519	0.434	0.510	0.822
7	-0.130	-0.437	-0.591	-0.294	-0.389	-0.365
8	-0.053	-0.196	-0.265	-0.132	-0.174	-0.156
9	-0.033	-0.199	-0.155	-0.125	-0.053	-0.115
10	-0.047	-0.157	-0.213	-0.106	-0.140	0.048
11	-0.044	-0.147	-0.199	-0.099	-0.131	-0.135
12	-0.015	0.003	0.221	-0.033	-0.044	-0.072
13	-0.077	-0.257	-0.347	-0.173	-0.229	-0.200
14	0.044	-0.312	0.199	0.074	0.131	0.122
15	0.147	-0.132	0.103	-0.034	0.438	0.306
16	-0.037	0.406	-0.101	0.020	-0.149	-0.147
17	0.020	0.296	0.475	0.999	0.193	0.548
18	-0.067	-0.224	-0.304	-0.151	-0.200	-0.256
19	0.000	0.707	0.113	-0.018	0.073	0.001
20	0.028	0.194	0.512	0.918	0.232	0.536
21	-0.040	-0.134	-0.181	-0.090	-0.119	-0.074
22	-0.023	-0.094	-0.127	-0.063	-0.084	-0.119
23	-0.023	-0.077	-0.104	-0.052	-0.069	0.097
24	-0.032	-0.108	-0.145	-0.072	-0.096	-0.142
25	-0.032	-0.107	-0.144	-0.072	-0.095	-0.062
26	-0.015	-0.049	-0.067	-0.033	-0.044	-0.076
27	-0.028	0.233	0.419	0.973	0.113	0.503
28	-0.070	-0.234	-0.316	-0.157	-0.208	-0.155
29	0.024	0.133	0.246	0.211	-0.012	-0.026
30	-0.056	0.312	0.835	0.472	0.550	0.515
31	-0.015	-0.049	-0.067	-0.033	-0.044	-0.076
32	0.0	0.0	0.0	0.0	0.0	0.0
33	-0.047	0.354	0.555	0.445	0.197	0.217
34	-0.058	0.287	0.789	0.448	0.520	0.476
35	-0.037	0.093	0.562	0.135	0.852	0.554
36	-0.026	0.814	0.051	0.013	-0.077	0.077
37	-0.034	-0.114	-0.154	-0.076	-0.101	-0.144
38	0.0	0.0	0.0	0.0	0.0	0.0
39	-0.019	0.073	-0.072	-0.034	-0.057	-0.050
40	-0.037	0.005	-0.048	-0.061	-0.112	-0.114
41	-0.021	-0.070	-0.093	-0.047	-0.063	-0.091
42	-0.022	-0.074	-0.100	-0.050	-0.066	-0.081
43	-0.019	0.047	-0.053	-0.029	-0.053	-0.041
44	1.000	0.065	0.221	0.021	0.335	0.234
45	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0
47	1.000	0.063	0.221	0.021	0.335	0.234
48	1.000	0.065	0.221	0.021	0.335	0.234
49	1.000	0.065	0.221	0.021	0.335	0.234
50	0.0	0.0	0.0	0.0	0.0	0.0
51	1.000	0.065	0.221	0.021	0.335	0.234
52		1.000	0.391	0.298	0.135	0.257
53			1.000	0.479	0.059	0.567
54				1.000	0.195	0.551
55					1.000	0.636
56						1.000

SUB-PROBLM 1
DEPENDENT VARIABLE 5
MAXIMUM NUMBER OF STEPS 7
F-LEVEL FOR INCLUSION 0.010000
F-LEVEL FOR DELETION 0.005000
TOLERANCE LEVEL 0.001000

STEP NUMBER 1
VARIABLE ENTERED 19

MULTIPLE R 0.0739
STD. ERROR OF EST. 1.2845

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	1	0.608	0.608	0.368
RESIDUAL	67	110.539	1.650	

VARIABLES IN EQUATION				
VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.21896)		
MEM	5	1.77166	0.31935	30.6817 (2)
16/17	19	-9.21194	5.95342	2.3942 (8)

VARIABLES NOT IN EQUATION				
VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	-0.07320	0.4341	0.3501 (2)
LS	2	0.02138	0.9219	0.0297 (2)
L	3	0.10363	0.9505	0.7056 (2)
H	4	-0.13262	0.9600	1.2735 (2)

VARIABLES IN EQUATION				
VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.59835)		
16/17	19	3.97757	6.55463	0.3682 (3)

VARIABLES NOT IN EQUATION				
VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	0.38161	0.9874	11.2495 (2)
LS	2	-0.07074	0.9451	0.3319 (2)
L	3	0.20884	1.0000	3.0099 (2)
H	4	-0.21330	0.9920	3.1613 (2)
MEM	5	0.56334	0.8400	30.6816 (2)
DIG	7	-0.39239	0.9132	12.0473 (2)
LIN	8	-0.08421	0.9336	0.4713 (2)
OTHER	9	-0.08364	0.9848	0.4649 (2)
ECL	10	0.22585	0.9894	3.5477 (2)
CMOS	11	-0.18120	0.9907	2.2407 (2)
MOS	12	-0.13390	0.9990	1.2050 (2)
NG	13	-0.16526	0.9718	1.8532 (2)
HERMET	14	0.27450	0.8455	5.3783 (2)
FP	15	0.39477	0.9881	12.1846 (2)
REL	16	-0.33116	0.8610	8.1295 (2)
MS	17	0.43395	0.9999	15.3122 (2)
16/13	18	-0.42724	0.9784	14.7371 (2)
	20	0.46775	0.9935	18.4847 (2)
	21	-0.03398	0.9923	0.0763 (2)
	22	-0.17102	0.9962	1.9826 (2)
	23	0.19166	0.9974	2.5168 (2)
	24	-0.25111	0.9950	4.4418 (2)
	25	0.00131	0.9951	0.0001 (2)
	26	-0.13911	0.9990	2.4473 (2)
	27	0.37807	0.9986	11.0069 (2)
	28	-0.06094	0.9756	0.2460 (2)
	29	-0.06450	0.9852	0.2753 (1)
	30	0.45442	0.7942	17.1752 (2)
	31	-0.19911	0.9990	2.4478 (2)
	32	0.0	0.0	0.0 (2)
	33	0.17643	0.9962	2.1205 (2)
	34	0.38161	0.9874	11.2495 (2)
	35	0.40862	0.9913	13.2289 (2)
	36	0.16043	0.5641	1.7435 (2)
	37	-0.17603	0.9945	2.1104 (2)
	38	0.0	0.0	0.0 (2)
	39	-0.04390	0.9376	0.1274 (2)
	40	-0.11232	0.9980	0.8433 (2)
	41	-0.12019	0.9979	0.9674 (2)
	42	-0.04337	0.9976	0.1244 (2)
	43	-0.02720	0.9657	0.0489 (2)
	44	0.20884	1.0000	3.0099 (2)
	45	0.0	0.0	0.0 (2)
	46	0.0	0.0	0.0 (2)
	47	0.20885	1.0000	3.0100 (2)
	48	0.20884	1.0000	3.0099 (2)
	49	0.20884	1.0000	3.0099 (2)
	50	0.0	0.0	0.0 (2)
	51	0.20885	1.0000	3.0100 (2)
	52	0.40584	0.5009	13.0141 (2)
	53	0.51519	0.9373	23.8470 (2)
	54	0.43667	0.9997	15.5499 (2)
	55	0.50708	0.9946	22.8442 (2)
	56	0.82391	1.0000	139.4934 (1)

STEP NUMBER 2
VARIABLE ENTERED 5

MULTIPLE R 0.5666
STD. ERROR OF EST. 1.0693

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	2	35.687	17.843	15.607
RESIDUAL	66	75.460	1.143	

DIG	7	-0.08527	0.5908	0.4761 (2)
LIN	8	0.07595	0.9178	0.3872 (2)
OTHER	9	0.00733	0.9599	0.0035 (2)
ECL	10	0.42381	0.7499	14.2314 (2)
CMOS	11	-0.08900	0.9536	0.5190 (2)
MOS	12	-0.33303	0.9429	8.2122 (2)
NG	13	0.03442	0.8589	0.0781 (2)
HERMET	14	0.20173	0.8126	2.7574 (2)
FP	15	0.41212	0.9733	13.2997 (2)
REL	16	-0.32673	0.8531	8.3111 (2)
NB	17	0.21067	0.7469	3.0247 (2)
16/13	18	-0.32929	0.6919	7.9054 (2)
	20	0.23645	0.7095	3.8494 (2)
	21	0.07997	0.9617	0.4184 (2)
	22	-0.12410	0.9812	1.0257 (2)
	23	0.30256	0.9372	6.5476 (2)
	24	-0.20971	0.9752	2.9902 (2)
	25	0.09806	0.9756	0.6311 (2)
	26	-0.18525	0.9948	2.3099 (2)
	27	0.17592	0.8259	2.0758 (2)
	28	0.14466	0.8228	1.3893 (2)
	29	-0.24194	0.9327	4.0413 (1)
	30	0.01410	0.3635	0.0129 (2)
	31	-0.18525	0.9948	2.3099 (2)
	32	0.0	0.0	0.0 (2)
	33	-0.17244	0.7185	1.9920 (2)
	34	-0.07320	0.4341	0.3501 (2)
	35	0.15818	0.7145	1.6621 (2)
	36	0.10123	0.5554	0.6730 (2)
	37	-0.11262	0.9724	0.8350 (2)
	38	0.0	0.0	0.0 (2)
	39	0.04324	0.9190	0.1218 (2)
	40	-0.10014	0.9952	0.6584 (2)
	41	-0.08307	0.9894	0.4517 (2)
	42	0.01394	0.9992	0.0126 (2)
	43	0.04303	0.9538	0.1228 (2)
	44	0.10363	0.9505	0.7056 (2)
	45	0.0	0.0	0.0 (2)
	46	0.0	0.0	0.0 (2)
	47	0.10363	0.9505	0.7057 (2)
	48	0.10363	0.9505	0.7056 (2)
	49	0.10363	0.9505	0.7056 (2)
	50	0.0	0.0	0.0 (2)
	51	0.10363	0.9505	0.7057 (2)
	52	0.08825	0.3086	0.5103 (2)
	53	-0.13571	0.8560	1.2196 (2)
	54	0.20938	0.7392	2.9953 (2)
	55	0.23410	0.5933	3.7606 (2)
	56	0.73209	0.6148	75.0721 (1)

STEP NUMBER 3
VARIABLE ENTERED 10

MULTIPLE R 0.6656
STD. ERROR OF EST. 0.9759

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	3	49.241	16.414	17.234
RESIDUAL	65	61.706	0.952	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		-0.01987)		
MEM	5	2.00489	0.29840	45.1436 (2)
ECL	10	1.35240	0.35849	14.2314 (2)
16/17	19	-8.95905	5.43404	2.7182 (8)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	-0.06497	0.4336	0.2713 (2
LS'	2	0.06889	0.9134	0.3052 (2)
L	3	0.11494	0.9505	0.8568 (2)
N	4	-0.06774	0.9273	0.2951 (2)
DIG	7	-0.23706	0.5430	3.3129 (2)
LIN	8	0.21399	0.8504	3.2550 (2)
OTHER	9	0.16956	0.8583	1.8946 (2)
CMOS	11	-0.00435	0.9155	0.0015 (2)
MOS	12	-0.36700	0.9429	9.9619 (2)
NG	13	0.05432	0.8579	0.1894 (2)
HERMET	14	0.22128	0.8126	3.2950 (2)
FP	15	0.43614	0.9767	15.0339 (2)
REL	16	-0.38706	0.8522	11.2780 (2)
NB	17	0.23611	0.7468	3.7785 (2)
16/13	18	-0.47372	0.8484	19.0273 (2)

20	0.26320	0.7095	4.7634 (2)
21	0.07090	0.9606	0.3410 (2)
22	-0.07392	0.9657	0.4012 (2)
23	0.12450	0.7592	1.0076 (2)
24	-0.16566	0.9548	1.8059 (2)
25	-0.27460	0.5402	5.2193 (2)
26	-0.17425	0.9905	2.0040 (2)
27	0.19557	0.8059	2.5452 (2)
28	0.15705	0.8827	1.6186 (2)
29	-0.30125	0.9279	6.3980 (1)
30	0.01749	0.3636	0.0196 (2)
31	-0.17424	0.9905	2.0039 (2)
32	0.0	0.0	0.0 (2)
33	-0.17077	0.7172	1.9224 (2)
34	-0.06497	0.4336	0.2713 (2)
35	0.17550	0.7145	2.0337 (2)
36	0.10740	0.5534	0.7468 (2)
37	-0.05350	0.9497	0.1837 (2)
38	0.0	0.0	0.0 (2)
39	0.07969	0.9148	0.4091 (2)
40	-0.04594	0.9760	0.1353 (2)
41	-0.04813	0.9808	0.1436 (2)
42	0.06203	0.9785	0.2472 (2)
43	0.07753	0.9499	0.3370 (2)
44	0.11494	0.9505	0.8568 (2)
45	0.0	0.0	0.0 (2)
46	0.0	0.0	0.0 (2)
47	0.11494	0.9505	0.8569 (2)
48	0.11494	0.9505	0.8568 (2)
49	0.11494	0.9505	0.8568 (2)
50	0.0	0.0	0.0 (2)
51	0.11494	0.9505	0.8569 (2)
52	0.09253	0.3085	0.5527 (2)
53	-0.14354	0.0660	1.3464 (2)
54	0.23321	0.7392	3.6810 (2)
55	0.25935	0.5938	4.6344 (2)
56	0.71982	0.5822	68.8172 (1)

STEP NUMBER 4
VARIABLE ENTERED 18

MULTIPLE R 0.7554
STD. ERROR OF EST. 0.8635

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	4	63.423	15.857	21.267
RESIDUAL	64	47.719	0.746	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.29312)		
MEM	5	1.69924	0.27316	38.6969 (2)
ECL	10	1.66570	0.32523	26.2316 (2)
16/13	13	-0.23799	0.05456	19.0273 (2)
16/17	19	-9.29049	4.80865	3.7328 (8)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	-0.02735	0.4304	0.0472 (2)
LS	2	0.02085	0.9031	0.0274 (2)
L	3	0.13013	0.9505	1.0852 (2)
H	4	-0.13398	0.9157	1.2409 (2)
DIG	7	-0.32827	0.5372	7.6091 (2)
LIN	8	0.32558	0.8335	7.4701 (2)
OTHER	9	0.23306	0.8526	3.7848 (2)
CMOS	11	0.02175	0.9132	0.0298 (2)
MOS	12	-0.41911	0.9429	13.4245 (2)
NG	13	-0.09383	0.7896	0.5840 (2)
HERMET	14	-0.01743	0.6174	0.0191 (2)
FP	15	0.39914	0.9404	11.9388 (2)
REL	16	-0.14254	0.5461	1.3066 (2)
NS	17	0.25402	0.7468	4.7205 (2)
	20	0.29360	0.7095	6.0756 (2)
	21	-0.03333	0.9138	0.0927 (2)
	22	-0.11876	0.9631	0.9012 (2)
	23	0.03701	0.7308	0.0964 (2)
	24	-0.14613	0.9489	1.3747 (2)
	25	-0.04533	0.4042	0.1297 (2)
	26	-0.09357	0.9526	0.5565 (2)
	27	0.22074	0.8059	3.2271 (2)
	28	-0.00284	0.7249	0.0005 (2)
	29	-0.26450	0.9072	4.7390 (1)
	30	0.01706	0.3636	0.0183 (2)
	31	-0.09357	0.9526	0.5565 (2)
	32	0.0	0.0	0.0 (2)
	33	-0.13186	0.7075	1.1247 (2)

34	-0.02735	0.4304	0.0472 (2)
35	0.19061	0.7145	2.5072 (2)
36	0.12886	0.5533	1.0638 (2)
37	-0.12435	0.9370	0.9976 (2)
38	0.0	0.0	0.0 (2)
39	0.04486	0.9083	0.1270 (2)
40	-0.11029	0.9652	0.7758 (2)
41	-0.10055	0.9740	0.6434 (2)
42	0.01109	0.9663	0.0077 (2)
43	0.04236	0.9415	0.1214 (2)
44	0.13013	0.9505	1.0852 (2)
45	0.0	0.0	0.0 (2)
46	0.0	0.0	0.0 (2)
47	0.13013	0.9505	1.0853 (2)
48	0.13013	0.9505	1.0852 (2)
49	0.13013	0.9505	1.0852 (2)
50	0.0	0.0	0.0 (2)
51	0.13013	0.9505	1.0853 (2)
52	0.11274	0.3035	0.8110 (2)
53	-0.17293	0.0560	1.9421 (2)
54	0.26341	0.7392	4.6972 (2)
55	0.29389	0.5937	5.9557 (2)
56	0.74285	0.5675	77.5717 (2)

STEP NUMBER 5
VARIABLE ENTERED 12

MULTIPLE R 0.8039
STD. ERROR OF EST. 0.7902

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	5	71.[illegible]	14.362	23.001
RESIDUAL	63	39.33[illegible]	0.624	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.29523)		
MEM	5	1.90967	0.25648	55.4362 (2)
ECL	10	1.66451	0.29762	31.2792 (2)
MOS	12	-3.00344	0.81973	13.4245 (2)
16/13	18	-0.23336	0.04993	22.7918 (2)
16/17	19	-11.35440	4.43636	6.5505 (8)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	-0.21182	0.3739	2.9126 (2)
LS	2	0.03167	0.9028	0.0623 (2)
L	3	0.11074	0.9457	0.7698 (2)
H	4	-0.15396	0.9157	1.5053 (2)
DIG	7	-0.36413	0.5371	9.4774 (2)
LIN	8	0.35735	0.8355	9.0581 (2)
OTHER	9	0.23687	0.8500	3.6035 (2)
CMOS	11	0.02316	0.9132	0.0333 (2)
NG	13	-0.10715	0.7896	0.7201 (2)
HERMET	14	-0.02680	0.6172	0.0446 (2)
FP	15	0.38065	0.9231	10.5055 (2)
REL	16	-0.18559	0.5441	2.2117 (2)
NB	17	0.20992	0.7218	2.8583 (2)
	20	0.23939	0.6812	3.7691 (2)
	21	-0.04334	0.9138	0.1150 (2)
	22	-0.13137	0.9630	1.0838 (2)
	23	0.04058	0.7308	0.1023 (2)
	24	-0.16148	0.9439	1.6600 (2)
	25	-0.04938	0.4042	0.1516 (2)
	26	-0.10315	0.9526	0.6663 (2)
	27	0.17469	0.7371	1.9517 (2)
	28	-0.00464	0.7349	0.0013 (2)
	29	-0.35463	0.8917	8.9190 (1)
	30	-0.18495	0.3034	2.1958 (2)
	31	-0.10315	0.9526	0.6668 (2)
	32	0.0	0.0	0.0 (2)
	33	-0.24643	0.6770	4.0085 (2)
	34	-0.21182	0.3739	2.9126 (2)
	35	0.13193	0.6877	1.0966 (2)
	36	0.12348	0.5524	0.9600 (2)
	37	-0.13326	0.9370	1.2083 (2)
	38	0.0	0.0	0.0 (2)
	39	0.05988	0.9078	0.2232 (2)
	40	-0.13451	0.9644	1.1424 (2)
	41	-0.11121	0.9740	0.7764 (2)
	42	0.01170	0.9658	0.0085 (2)
	43	0.05501	0.9433	0.1882 (2)
	44	0.11074	0.9457	0.7698 (2)
	45	0.0	0.0	0.0 (2)
	46	0.0	0.0	0.0 (2)
	47	0.11075	0.9457	0.7699 (2)

48	0.11074	0.9457	0.7698 (2)
49	0.11074	0.9457	0.7698 (2)
50	0.0	0.0	0.0 (2)
51	0.11075	0.9457	0.7699 (2)
52	0.05859	0.3021	0.2136 (2)
53	-0.19592	0.0660	2.4749 (2)
54	0.20323	0.7138	2.8101 (2)
55	0.21263	0.5549	2.9359 (2)
56	0.71259	0.5166	63.9601 (1)

STEP NUMBER 6
VARIABLE ENTERED 15

MULTIPLE R 0.8351
STD. ERROR OF EST. 0.7366

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	6	77.509	12.918	23.811
RESIDUAL	62	33.637	0.543	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.02207)		
MEM	5	1.34461	0.23992	59.1106 (2)
ECL	10	1.58316	0.27842	32.5373 (2)
MOS	12	-2.66517	0.77120	11.9430 (2)
FP	15	0.60918	0.15795	10.5056 (2)
I5/13	18	-0.20841	0.04745	19.2923 (2)
I6/17	19	-9.15497	4.19064	4.7726 (8)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	-0.21104	0.3731	2.8434 (2)
LS	2	0.09004	0.8919	0.3933 (2)
L	3	0.06941	0.9312	0.2953 (2)
H	4	-0.17102	0.9156	1.8378 (2)
DIG	7	-0.36066	0.5334	9.1213 (2)
LIN	8	0.34022	0.3248	8.0915 (2)
OTHER	9	0.21521	0.8411	2.9625 (2)
CMOS	11	0.02337	0.9132	0.0348 (2)
NG	13	-0.04782	0.7676	0.1398 (2)
HERMET	14	-0.11446	0.5921	0.8098 (2)
REL	16	-0.04755	0.4552	0.1383 (2)
NB	17	0.28547	0.7081	5.4533 (2)
	20	0.31161	0.6720	6.5599 (2)
	21	0.00443	0.3998	0.0012 (2)
	22	-0.03105	0.9412	0.4034 (2)
	23	0.00336	0.7239	0.0009 (2)
	24	-0.11745	0.9293	0.3533 (2)
	25	-0.00991	0.3997	0.0060 (2)
	26	-0.03641	0.9490	0.4589 (2)
	27	0.25376	0.7593	4.1984 (2)
	28	0.03390	0.7779	0.0702 (2)
	29	-0.29432	0.8416	5.7853 (2)
	30	-0.19328	0.3034	2.3672 (2)
	31	-0.08641	0.9490	0.4589 (2)
	32	0.0	0.0	0.0 (2)
	33	-0.19295	0.6533	2.3538 (2)
	34	-0.21104	0.3731	2.8434 (2)
	35	-0.01903	0.5337	0.0221 (2)
	36	0.20357	0.5376	2.6371 (2)
	37	-0.14409	0.9368	1.2932 (2)
	38	0.0	0.0	0.0 (2)
	39	0.10875	0.8977	0.7300 (2)
	40	-0.11822	0.9601	0.8647 (2)
	41	-0.21233	0.9302	2.8815 (2)
	42	0.05333	0.9572	0.1773 (2)
	43	0.10493	0.9321	0.6797 (2)
	44	0.06941	0.9312	0.2953 (2)
	45	0.0	0.0	0.0 (2)
	46	0.0	0.0	0.0 (2)
	47	0.06942	0.9312	0.2954 (2)
	48	0.06941	0.9312	0.2953 (2)
	49	0.06941	0.9312	0.2953 (2)
	50	0.0	0.0	0.0 (2)
	51	0.06942	0.9312	0.2954 (2)
	52	0.16728	0.2946	1.7561 (2)
	53	-0.24937	0.0654	4.0449 (2)
	54	0.29255	0.7012	5.2924 (2)
	55	0.02816	0.4165	0.0484 (2)
	56	0.68529	0.5794	54.0130 (1)

STEP NUMBER 7
VARIABLE ENTERED 7

MULTIPLE R 0.8583
STD. ERROR OF EST. 0.6926

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	7	81.885	11.698	24.386
RESIDUAL	61	29.262	0.480	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.52165)		
MEM	5	1.38197	0.27249	25.6833 (2)
DIG	7	-0.69142	0.22893	9.1213 (2)
ECL	10	1.84202	0.27497	44.8779 (2)
MOS	12	[illegible]	0.70527	13.8805 (2)
FP	15	0.55445	0.17735	10.1300 (2)
16/13	18	-0.22443	0.04495	24.9495 (2)
16/17	19	-9.83248	3.94688	6.2061 (8)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
S	1	-0.20873	0.3724	2.7332 (2)
LS	2	0.01634	0.2629	0.0160 (2)
L	3	0.07676	0.9312	0.3556 (2)
H	4	-0.06678	0.2276	0.2683 (2)
LIN	8	0.00052	0.0330	0.0000 (2)
OTHER	9	0.07526	0.6927	0.3418 (2)
CMOS	11	0.06125	0.9056	0.2250 (2)
NG	13	0.03537	0.7298	0.0752 (2)
HERMET	14	-0.12760	0.5920	0.9930 (2)
REL	16	-0.04221	0.4650	0.1071 (2)
N3	17	0.29256	0.7071	5.6161 (2)
	20	0.32337	0.6705	7.0067 (2)
	21	0.07100	0.8742	0.3040 (2)
	22	-0.05033	0.9327	0.1524 (2)
	23	-0.00071	0.7233	0.0000 (2)
	24	-0.10415	0.9268	0.6579 (2)
	25	0.00952	0.3956	0.0054 (2)
	26	-0.04295	0.9331	0.1109 (2)
	27	0.26235	0.7638	4.4532 (2)
	28	0.09577	0.7602	0.5554 (2)
	29	-0.31127	0.8415	6.4370 (1)
	30	-0.21487	0.3032	2.9043 (2)
	31	-0.04294	0.9331	0.1108 (2)
	32	0.0	0.0	0.0 (2)
	33	-0.18443	0.6511	2.1127 (2)
	34	-0.20873	0.3724	2.7332 (2)
	35	-0.00995	0.5333	0.0059 (2)
	36	0.22580	0.5374	3.2236 (2)
	37	-0.05949	0.3780	0.2131 (2)
	38	0.0	0.0	0.0 (2)
	39	0.02793	0.8497	0.0463 (2)
	40	-0.04179	0.9126	0.1050 (2)
	41	-0.16331	0.9024	1.6440 (2)
	42	0.11732	0.9355	0.8374 (2)
	43	0.02157	0.8793	0.0279 (2)
	44	0.07676	0.9312	0.3556 (2)
	45	0.0	0.0	0.0 (2)
	46	0.0	0.0	0.0 (2)
	47	0.07676	0.9312	0.3556 (2)
	48	0.07676	0.9312	0.3556 (2)
	49	0.07676	0.9312	0.3556 (2)
	50	0.0	0.0	0.0 (2)
	51	0.07676	0.9312	0.3556 (2)
	52	0.18598	0.2946	2.1436 (2)
	53	-0.28322	0.0653	5.2325 (2)
	54	0.29301	0.7008	5.6683 (2)
	55	0.04337	0.4160	0.1131 (2)
	56	0.70137	0.4751	58.0930 (1)

SPECIFIED STEP REACHED

SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED		VARIABLE REMOVED	MULTIPLE R	RSQ	INCREASE IN RSQ	F VALUE TO ENTER OR REMOVE
1	16/17	19		0.0739	0.0055	0.0055	0.3682
2	MEM	5		0.5666	0.3211	0.3156	30.6817
3	ECL	10		0.6656	0.4430	0.1219	14.2314
4	16/13	18		0.7554	0.5707	0.1276	19.0273
5	MOS	12		0.8038	0.6461	0.0754	13.4245
6	FP	15		0.8351	0.6974	0.0513	10.5056
7	DIG	7		0.8583	0.7367	0.0394	9.1213

AD-A111 850 HUGHES AIRCRAFT CO. FULLERTON CA F/G 9/5
MICROCIRCUIT COST FACTORS.(U)
DEC 81 L E JAMES, J S PERRY, D R KING F30602-80-C-0051
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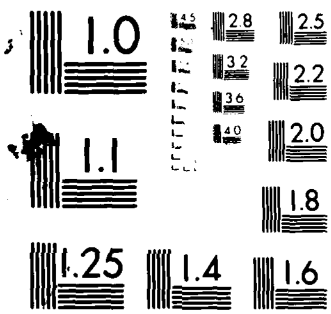


MICROCOPY RESOLUTION TEST CHART

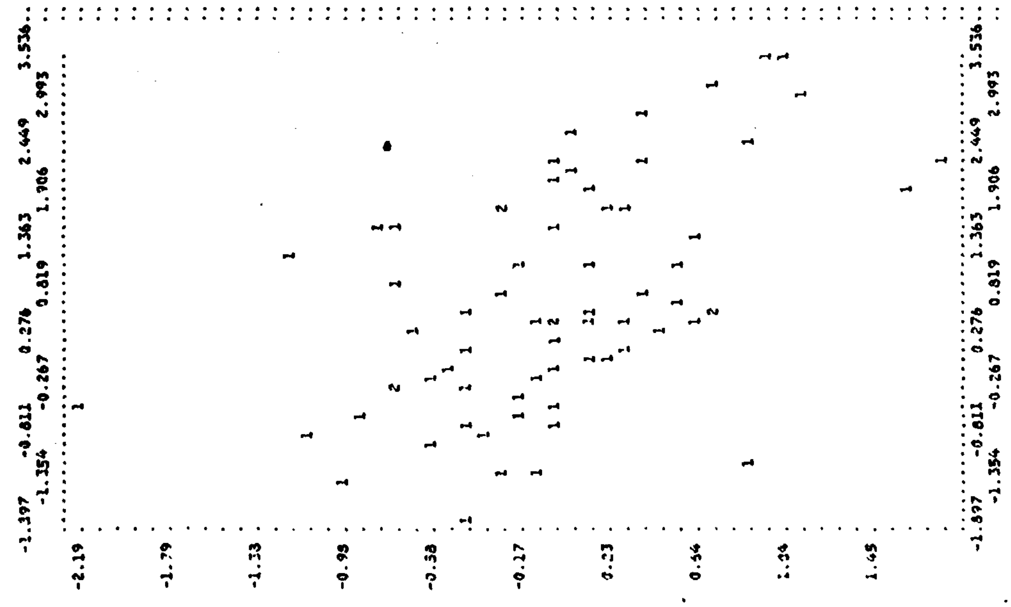
NATIONAL BUREAU OF STANDARDS 1963 A

LIST OF RESIDUALS

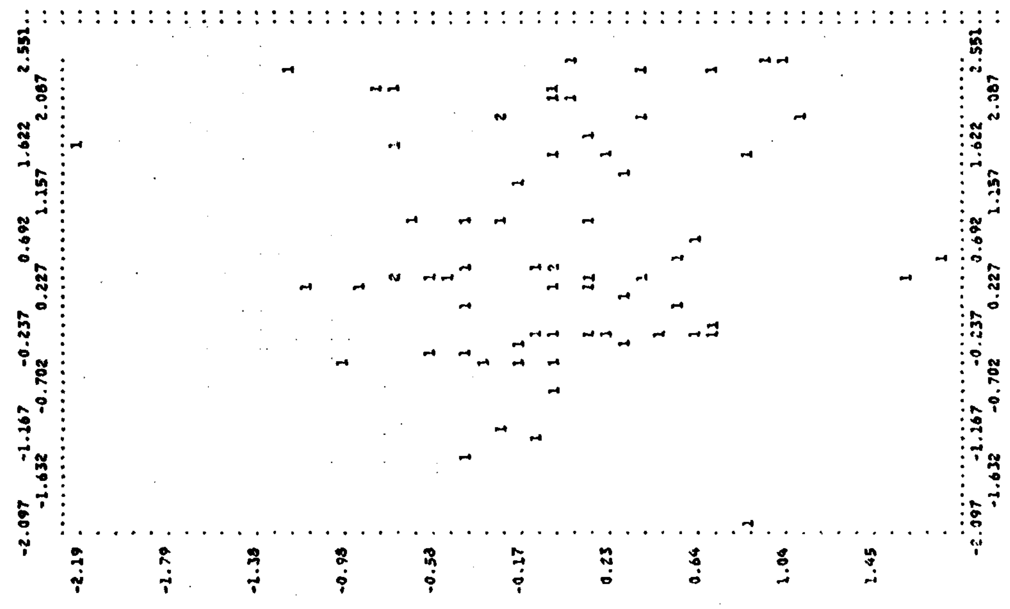
CASE NUMBER	Y X(6)	Y COMPUTED	RESIDUAL	X(19)	X(5)	X(10)	X(18)	X(12)
1	-0.1997	-0.2072	0.0075	0.0	0.0	0.0	0.1667	0.0
2	0.3365	0.3807	-0.0442	0.0	0.0	0.0	0.0625	0.0
3	-0.0222	-0.2147	0.1925	0.0	0.0	0.0	0.2000	0.0
4	-0.6733	-0.5345	-0.1388	0.0	0.0	0.0	1.6250	0.0
5	-0.2319	0.3666	-0.5985	0.0	0.0	0.0	0.1250	0.0
6	0.3920	0.3722	0.0198	0.0	0.0	0.0	0.1000	0.0
7	0.3001	-0.2118	0.5119	0.0	0.0	0.0	0.1875	0.0
8	0.3436	-0.2820	0.6256	0.0	0.0	0.0	0.5000	0.0
9	0.7324	0.3229	0.4095	0.0	0.0	0.0	0.3200	0.0
10	0.0276	0.4522	-0.4246	0.0	0.0	0.0	0.3095	0.0
11	0.2271	0.9178	-0.6907	0.0	0.0	0.0	0.7500	0.0
12	0.9933	0.4768	0.5165	0.0	0.0	0.0	0.2000	0.0
13	0.6663	0.9178	-0.2515	0.0	0.0	0.0	0.7500	0.0
14	-0.1985	0.3222	-0.5207	0.0	0.0	0.0	0.8389	0.0
15	0.4606	0.3136	0.1470	0.0	0.0	0.0	0.3611	0.0
16	-0.3633	0.3567	-0.7205	0.0	0.0	0.0	3.2500	0.0
17	-1.3665	-1.2919	-0.0746	0.0	0.0	0.0	5.0000	0.0
18	-1.2040	-2.0967	0.8927	0.0	0.0	0.0	11.6667	0.0
19	-1.4397	-0.4719	-0.9678	0.0	0.0	0.0	1.3462	0.0
20	-1.3744	-1.1516	-0.2228	0.0	0.0	0.0	4.3750	0.0
21	-0.5534	-0.5345	-0.0139	0.0	0.0	0.0	1.6250	0.0
22	1.9459	0.3199	1.6260	0.0	0.0	0.0	0.3333	0.0
23	-1.8972	-1.4789	-0.4183	0.0	0.0	0.0	5.8333	0.0
24	1.0818	1.2234	-0.1416	0.0	0.0	1.0000	2.0000	0.0
25	2.1401	2.0684	0.0717	0.0	0.0	1.0000	0.7500	0.0
26	-0.3567	0.3631	-0.7198	0.0	0.0	1.0000	5.8333	0.0
27	1.4540	2.2184	-0.7644	0.0254	1.0000	0.0	0.0	0.0
28	2.2513	1.8940	0.3573	0.0010	1.0000	0.0	0.0	0.0
29	0.5878	0.0677	0.5201	0.1857	1.0000	0.0	0.0	0.0
30	3.4012	2.4584	0.9428	0.0010	1.0000	0.0	0.0	0.0
31	2.8034	2.4056	0.3978	0.0063	1.0000	0.0	0.0	0.0
32	2.4204	1.5675	0.8529	0.0342	1.0000	0.0	0.0	0.0
33	-0.5961	1.5964	-2.1925	0.0313	1.0000	0.0	0.0	0.0
34	1.6409	1.8616	-0.2207	0.0043	1.0000	0.0	0.0	0.0
35	2.9257	1.8388	1.0869	0.0005	1.0000	0.0	0.0	0.0
36	1.4351	2.2184	-0.7833	0.0254	1.0000	0.0	0.0	0.0
37	3.4275	2.4168	1.0107	0.0032	1.0000	0.0	0.0	0.0
38	1.8795	1.7356	0.1439	0.0171	1.0000	0.0	0.0	0.0
39	1.1474	2.3528	-1.2054	0.0117	1.0000	0.0	0.0	0.0
40	1.6409	1.8616	-0.2207	0.0043	1.0000	0.0	0.0	0.0
41	0.1823	0.1856	-0.0033	0.0342	0.0	0.0	0.0	0.0
42	2.5533	2.4524	0.1009	0.0016	1.0000	0.0	0.0	0.0
43	-1.0642	-0.4690	-0.5952	0.0	0.0	0.0	1.3333	0.0
44	0.5247	0.9178	-0.3931	0.0	0.0	0.0	0.7500	0.0
45	2.2246	2.2253	-0.0007	0.0	0.0	1.0000	0.0508	0.0
46	0.9933	0.8430	0.1503	0.0	0.0	0.0	1.0833	0.0
47	0.3485	0.4094	-0.0609	0.0	0.0	0.0	0.5000	0.0
48	0.4055	0.0955	0.3100	0.0	0.0	0.0	1.3333	0.0
49	-0.7995	-0.7955	-0.0040	0.0	1.0000	0.0	0.0	1.0000
50	2.2354	0.4655	1.7699	0.0	0.0	0.0	0.2500	0.0
51	-0.0030	-0.2072	0.2042	0.0	0.0	0.0	0.1667	0.0
52	0.5208	-0.1685	0.6893	0.0	0.0	0.0	0.0833	0.0
53	-0.8989	-0.5345	-0.3644	0.0	0.0	0.0	1.6250	0.0
54	-0.7700	-0.3942	-0.3758	0.0	0.0	0.0	1.0000	0.0
55	0.8671	1.5964	-0.7293	0.0313	1.0000	0.0	0.0	0.0

CASE NUMBER	Y X(6)	Y COMPUTED	RESIDUAL	X(19)	X(5)	X(10)	X(18)	X(12)
56	3.0564	2.3528	0.7036	0.0117	1.0000	0.0	0.0	0.0
57	-0.3467	0.0580	-0.4047	0.0	0.0	0.0	1.5000	0.0
58	-0.8989	0.2264	-1.1253	0.0	0.0	0.0	0.7500	0.0
59	0.5008	-0.1912	0.6920	0.0	0.0	0.0	0.0956	0.0
60	1.7047	1.5039	0.2008	0.0	0.0	1.0000	0.7500	0.0
61	2.0541	2.0684	-0.0143	0.0	0.0	1.0000	0.7500	0.0
62	0.0583	-0.2915	0.3498	0.0	0.0	1.0000	8.7500	0.0
63	1.6390	1.3390	0.3000	0.0	0.0	1.0000	4.0000	0.0
64	1.4469	1.4927	-0.0458	0.0	0.0	1.0000	0.8000	0.0
65	0.3646	0.2264	0.1382	0.0	0.0	0.0	0.7500	0.0
66	1.3900	0.7214	0.6686	0.0	0.0	0.0	1.6250	0.0
67	-0.7133	0.2195	-0.9328	0.0	0.0	0.0	1.3462	0.0
68	-0.4943	-0.3369	-0.1574	0.0	0.0	0.0	0.7447	0.0
69	-0.2984	-0.2317	-0.0667	0.0	0.0	0.0	0.2759	0.0

PLOT OF RESIDUALS (Y-AXIS)
VS. VARIABLE 6 (X-AXIS)



PLOT OF RESIDUALS (Y-AXIS)
VS. COMPUTED Y (X-AXIS)



REGRESSION ANALYSIS RESULTS FOR CARD ASSEMBLY (PCER2)

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```
LABELS  1CASSY    2NDEV    3NMC     4QA      5QB      6QB1     7QB2
0
LABELS  12TTLDTL  13ECL    14MOS    15IIL    18DIGLSI 19BIPMEM 20PINS
0
LABELS  21NDG     22NLG    23BITS   24NROM   25NRAM   26MC/DEV 27%MC**2
0
LABELS  38RA
0
(8X,F6.2,2X,18F3.0,2F6.0,F6.2,F6.0,2F3.0)
```

47562	77	50	0	9	41	0	0	0	0	0	1	0	0	49	50	0	0	0	1069	1000	0	0	0	0
41597	75	40	0	13	27	0	0	0	0	0	3	0	0	37	40	0	0	0	803	871	0	0	0	0
38609	41	24	0	4	20	0	0	0	0	0	1	0	0	23	24	0	0	0	516	404	0	0	0	0
44627	88	49	0	15	34	0	0	0	0	0	5	0	0	44	46	0	0	3	992	1080	0	5120	2	1
62954	92	47	0	3	44	0	0	0	0	0	18	0	0	29	31	0	0	16	1054	781	0	32768	16	0
50418	106	37	0	24	13	0	0	0	0	0	8	14	0	15	23	14	0	0	439	423	12250	0	0	0
49145	86	48	0	9	36	3	0	0	0	0	7	3	0	38	40	0	0	8	1023	939	0	13312	5	3
49356	138	12	0	5	1	6	0	0	0	0	0	7	0	5	5	7	0	0	70	16	4550	0	0	0
39282	82	42	0	11	31	0	0	0	0	0	2	0	0	40	42	0	0	0	867	1259	0	0	0	0
39059	42	28	0	20	8	0	0	0	0	0	1	0	0	27	28	0	0	0	464	284	0	0	0	0
46101	39	22	0	9	13	0	0	0	0	0	4	0	0	18	18	0	0	4	425	194	0	8192	4	0
168118	290	17	0	6	7	4	0	0	0	0	3	13	1	0	2	15	0	0	28	8	5600	0	0	0
107286	149	33	0	8	25	0	0	0	0	0	15	4	0	14	31	2	0	0	474	754	150	0	0	0
162736	226	15	2	2	5	8	0	0	0	0	3	7	2	3	6	7	0	0	134	56	1425	0	0	0
110347	82	42	0	8	34	0	0	0	0	0	25	0	0	17	18	0	0	24	894	195	0	24576	0	24
36962	67	43	0	8	35	0	0	0	0	0	1	0	0	42	43	0	0	0	917	970	0	0	0	0
102244	83	47	0	12	35	0	0	0	0	0	31	0	0	16	27	0	0	20	973	410	0	24576	4	16
39931	84	49	0	13	36	0	0	0	0	0	3	0	0	46	49	0	0	0	1010	1227	0	0	0	0
56006	52	31	0	10	21	0	0	0	0	0	7	0	0	24	24	0	0	7	623	278	0	14336	7	0
48024	134	43	0	18	23	2	0	0	0	0	32	3	0	8	41	1	1	0	760	777	525	0	0	0
37970	62	37	0	14	23	0	0	0	0	0	2	0	0	35	36	0	0	1	725	778	0	2048	1	0
50938	76	45	0	5	40	0	0	0	0	0	1	0	0	44	45	0	0	0	990	939	0	0	0	0

VARIABLE		MEAN	STANDARD DEVIATION
CASSY	1	649.66821	754.83984
NDEV	2	98.68181	114.80081
NMC	3	36.40909	38.23671
QA	4	0.09091	0.42640
QB	5	10.27273	11.62677
GB1	6	25.09090	28.01135
GB2	7	1.04545	2.42149
	8	0.0	0.0
	9	0.0	0.0
	10	0.0	0.0
	11	0.0	0.0
TTLDTL	12	7.86364	12.45172
ECL	13	2.31818	4.75299
MOS	14	0.13636	0.47673
IIL	15	26.09090	30.04088
	16	30.40909	33.48065
	17	2.09091	4.83039
DIGLSI	18	0.04545	0.21320
BIFMEM	19	3.77273	7.89419
PINS	20	693.18164	764.62671
NOG	21	620.13623	734.06665
NLG	22	11.13636	30.48500
BITS	23	5678.54297	11204.6016
NRCM	24	1.77273	4.03434
NRAM	25	2.00000	6.18649
MC/DEV	26	0.46949	0.50645
%MC**2	27	0.25649	0.29124
	28	0.04545	0.21320
	29	10.27273	11.62677
	30	75.27272	84.03409
	31	6.79545	15.73972
	32	10.31818	11.63654
	33	85.59090	93.32274
	34	92.38635	97.18217
	35	10.36364	11.65020
	36	10.36364	11.65020
	37	11.40909	12.45537
RA	38	10.80125	14.08563
	39	6.35031	6.36713

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10
1	1.000	0.952	0.756	0.460	0.665	0.702	0.625	0.0	0.0	0.0
2		1.000	0.749	0.420	0.694	0.673	0.707	0.0	0.0	0.0
3			1.000	0.084	0.884	0.977	0.241	0.0	0.0	0.0
4				1.000	0.037	0.038	0.704	0.0	0.0	0.0
5					1.000	0.773	0.215	0.0	0.0	0.0
6						1.000	0.153	0.0	0.0	0.0
7							1.000	0.0	0.0	0.0
8								0.0	0.0	0.0
9									0.0	0.0
10										0.0

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19	20
1	0.0	0.646	0.646	0.623	0.583	0.644	0.614	0.136	0.522	0.678
2	0.0	0.567	0.755	0.616	0.589	0.666	0.715	0.249	0.333	0.654
3	0.0	0.679	0.333	0.117	0.937	0.975	0.261	0.240	0.538	0.987
4	0.0	0.051	0.314	0.894	0.021	0.038	0.306	0.0	0.0	0.037
5	0.0	0.614	0.474	0.082	0.794	0.864	0.408	0.330	0.358	0.825
6	0.0	0.657	0.202	0.050	0.939	0.958	0.134	0.175	0.582	0.991
7	0.0	0.182	0.652	0.787	0.115	0.161	0.615	0.176	0.057	0.152
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12		1.000	0.268	0.069	0.407	0.566	0.180	0.548	0.761	0.657
13			1.000	0.542	0.146	0.226	0.900	0.135	0.029	0.190
14				1.000	0.019	0.040	0.567	0.0	0.0	0.037
15					1.000	0.969	0.094	0.057	0.365	0.953
16						1.000	0.140	0.261	0.379	0.974
17							1.000	0.044	0.0	0.118
18								1.000	0.0	0.212
19									1.000	0.570
20										1.000

VARIABLE NUMBER	21	22	23	24	25	26	27	28	29	30
1	0.578	0.406	0.507	0.349	0.436	0.668	0.606	0.460	0.665	0.702
2	0.626	0.515	0.348	0.290	0.233	0.626	0.553	0.420	0.694	0.673
3	0.937	0.254	0.564	0.472	0.375	0.956	0.917	0.084	0.884	0.977
4	0.016	0.100	0.0	0.0	0.0	0.028	0.003	1.000	0.037	0.038
5	0.794	0.467	0.360	0.279	0.269	0.863	0.818	0.037	1.000	0.773
6	0.938	0.120	0.615	0.522	0.398	0.935	0.906	0.038	0.773	1.000
7	0.127	0.383	0.067	0.069	0.027	0.134	0.088	0.704	0.215	0.153
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.498	0.165	0.724	0.468	0.662	0.563	0.486	0.051	0.614	0.657
13	0.191	0.904	0.034	0.035	0.014	0.193	0.108	0.314	0.474	0.202
14	0.016	0.264	0.0	0.0	0.0	0.036	0.004	0.894	0.082	0.058
15	0.955	0.128	0.413	0.400	0.201	0.952	0.949	0.021	0.794	0.939
16	0.978	0.156	0.419	0.390	0.226	0.949	0.924	0.038	0.864	0.958
17	0.112	0.911	0.0	0.0	0.0	0.140	0.065	0.306	0.408	0.134
18	0.226	0.037	0.0	0.0	0.0	0.135	0.075	0.0	0.330	0.175
19	0.311	0.0	0.957	0.632	0.859	0.511	0.483	0.0	0.355	0.582
20	0.943	0.127	0.600	0.504	0.395	0.960	0.934	0.037	0.825	0.991
21	1.000	0.120	0.363	0.371	0.152	0.886	0.857	0.016	0.794	0.938
22		1.000	0.0	0.0	0.0	0.156	0.083	0.100	0.467	0.120
23			1.000	0.829	0.674	0.544	0.516	0.0	0.360	0.615
24				1.000	0.146	0.470	0.449	0.0	0.279	0.522
25					1.000	0.342	0.320	0.0	0.269	0.398
26						1.000	0.991	0.028	0.863	0.935
27							1.000	0.003	0.818	0.906
28								1.000	0.037	0.038
29									1.000	0.773
30										1.000

VARIABLE NUMBER	31	32	33	34	35	36	37	38	39
1	0.625	0.673	0.716	0.789	0.680	0.680	0.758	0.637	0.895
2	0.707	0.701	0.694	0.781	0.706	0.703	0.799	0.603	0.886
3	0.241	0.835	0.990	0.990	0.885	0.835	0.875	0.808	0.942
4	0.704	0.055	0.041	0.154	0.073	0.073	0.205	0.088	0.248
5	0.215	1.000	0.821	0.823	0.999	0.999	0.976	0.523	0.868
6	0.153	0.773	0.997	0.982	0.773	0.773	0.753	0.871	0.886
7	1.000	0.227	0.166	0.321	0.240	0.240	0.419	0.183	0.463
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.182	0.615	0.668	0.671	0.615	0.615	0.610	0.562	0.651
13	0.652	0.479	0.242	0.338	0.484	0.484	0.580	0.181	0.516
14	0.787	0.098	0.064	0.189	0.115	0.115	0.260	0.115	0.333
15	0.115	0.794	0.944	0.926	0.794	0.794	0.765	0.765	0.842
16	0.161	0.864	0.970	0.958	0.864	0.864	0.839	0.763	0.837
17	0.615	0.413	0.172	0.265	0.418	0.418	0.511	0.141	0.459
18	0.176	0.330	0.199	0.219	0.329	0.329	0.342	0.076	0.207
19	0.057	0.355	0.568	0.555	0.354	0.354	0.343	0.588	0.500
20	0.152	0.825	0.996	0.981	0.825	0.825	0.801	0.831	0.892
21	0.127	0.794	0.944	0.927	0.793	0.793	0.767	0.749	0.821
22	0.383	0.468	0.167	0.222	0.469	0.469	0.513	0.099	0.377
23	0.067	0.360	0.599	0.536	0.359	0.359	0.349	0.692	0.523
24	0.069	0.278	0.505	0.496	0.278	0.278	0.273	0.719	0.435
25	0.027	0.269	0.392	0.381	0.269	0.269	0.257	0.275	0.350
26	0.134	0.863	0.949	0.933	0.862	0.862	0.833	0.773	0.907
27	0.080	0.817	0.916	0.894	0.816	0.816	0.779	0.745	0.857
28	0.704	0.055	0.041	0.154	0.073	0.073	0.205	0.088	0.248
29	0.215	1.000	0.821	0.823	0.999	0.999	0.976	0.523	0.868
30	0.153	0.773	0.997	0.982	0.773	0.773	0.753	0.871	0.886
31	1.000	0.227	0.166	0.321	0.240	0.240	0.419	0.183	0.463
32		1.000	0.821	0.825	1.000	1.000	0.979	0.524	0.872
33			1.000	0.987	0.821	0.821	0.800	0.849	0.906
34				1.000	0.827	0.827	0.836	0.845	0.946
35					1.000	1.000	0.982	0.525	0.875
36						1.000	0.982	0.525	0.875
37							1.000	0.527	0.908
38								1.000	0.765
39									1.000

SUB-PROBLM 1
DEPENDENT VARIABLE 1
MAXIMUM NUMCER CF STEPS 2
F-LEVEL FOR INCLUSION 0.010000
F-LEVEL FOR DELETION 0.005000
TOLERANCE LEVEL 0.001000

STEP NUMBER 1
VARIABLE ENTERED 2

MULTIPLE R 0.9525
STD. ERROR OF EST. 235.3682

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	1	11371868.0	11371868.0	205.275
RESIDUAL	21	1163362.00	55398.187	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
NDEV	2	6.26267	0.43711	205.2752 (9)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
NMC	3	0.21218	0.4392	0.9429 (9)
QA	4	0.21655	0.8238	0.9840 (2)
QB	5	0.01831	0.5187	0.0067 (2)
QB1	6	0.27056	0.5468	1.5797 (2)
QB2	7	-0.22238	0.5006	1.0405 (2)
	8	0.0	0.0	0.0 (2)
	9	0.0	0.0	0.0 (2)
	10	0.0	0.0	0.0 (2)
	11	0.0	0.0	0.0 (2)
TTLDTL	12	0.42280	0.6786	4.3534 (2)
ECL	13	-0.36506	0.4306	3.0753 (2)
MOS	14	0.15215	0.6202	0.4740 (2)
IIL	15	0.08738	0.6530	0.1539 (2)
	16	0.04520	0.5569	0.0409 (2)
	17	-0.31580	0.4887	2.2156 (2)
DIGLSI	18	-0.34361	0.9381	2.6775 (2)
BIPMEM	19	0.71353	0.8893	20.7639 (2)
PINS	20	0.24083	0.5722	1.2314 (2)
NDG	21	-0.07592	0.6086	0.1159 (2)
NLG	22	-0.32253	0.7348	2.3221 (2)
BITS	23	0.61267	0.8787	12.0187 (2)
NROM	24	0.24872	0.9159	1.3189 (9)
NRAM	25	0.72133	0.9457	21.6947 (9)
MC/DEV	26	0.30034	0.6079	1.9829 (2)
%MC**2	27	0.30906	0.6937	2.1121 (2)
	28	0.21654	0.8238	0.9840 (2)
	29	0.01831	0.5187	0.0067 (2)
	30	0.27056	0.5468	1.5797 (2)
	31	-0.22238	0.5006	1.0405 (2)
	32	0.02353	0.5087	0.0111 (2)
	33	0.25300	0.5189	1.3677 (2)
	34	0.23919	0.3908	1.2137 (2)
	35	0.02882	0.4991	0.0166 (2)
	36	0.02882	0.4991	0.0166 (2)
	37	-0.01922	0.3610	0.0074 (2)
RA	38	0.25902	0.6361	1.4384 (2)
	39	0.36234	0.2157	3.0226 (2)

STEP NUMBER 2
VARIABLE ENTERED 25

MULTIPLE R 0.9775
STD. ERROR OF EST. 167.0387

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	2	11977191.0	5988595.00	214.630
RESIDUAL	20	558038.375	27901.918	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
NDEV	2	5.91634	0.31900	343.9717 (9)
NRAM	25	27.57201	5.91959	21.6947 (9)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
NMC	3	-0.01897	0.3966	0.0068 (9)
QA	4	0.43075	0.8137	4.3286 (2)
QB	5	-0.13501	0.5064	0.3527 (2)
QB1	6	0.04377	0.4853	0.0365 (2)
QB2	7	-0.11540	0.4806	0.2564 (2)
	8	0.0	0.0	0.0 (2)
	9	0.0	0.0	0.0 (2)
	10	0.0	0.0	0.0 (2)
	11	0.0	0.0	0.0 (2)
TTLDTL	12	-0.10468	0.3817	0.2104 (2)
ECL	13	-0.27168	0.4029	1.3138 (2)

MOS	14	0.42253	0.5984	4.1294 (2)
IIL	15	0.04183	0.6487	0.0333 (2)
	16	-0.03663	0.5516	0.0255 (2)
	17	-0.20692	0.4593	0.8499 (2)
DIGLSI	18	-0.43281	0.9345	4.3795 (2)
BIPMEM	19	0.27267	0.2434	1.5261 (2)
PINS	20	0.00489	0.5101	0.0005 (2)
NDG	21	-0.11742	0.6086	0.2656 (2)
NLG	22	-0.31903	0.7195	2.1530 (2)
BITS	23	0.27268	0.5068	1.5262 (2)
NROM	24	0.27268	0.9094	1.5262 (9)
MC/DEV	26	0.16994	0.5672	0.5650 (2)
%MC**2	27	0.20688	0.6553	0.8495 (2)
	28	0.43075	0.8137	4.3286 (2)
	29	-0.13501	0.5064	0.3527 (2)
	30	0.04377	0.4853	0.0365 (2)
	31	-0.11540	0.4806	0.2564 (2)
	32	-0.12307	0.4969	0.3069 (2)
	33	0.02407	0.4628	0.0110 (2)
	34	0.00468	0.3489	0.0004 (2)
	35	-0.11693	0.4877	0.2634 (2)
	36	-0.11693	0.4877	0.2634 (2)
	37	-0.15414	0.3557	0.4624 (2)
RA	38	0.19600	0.6169	0.7591 (2)
	39	0.20151	0.1935	0.8041 (2)

SPECIFIED STEP REACHED

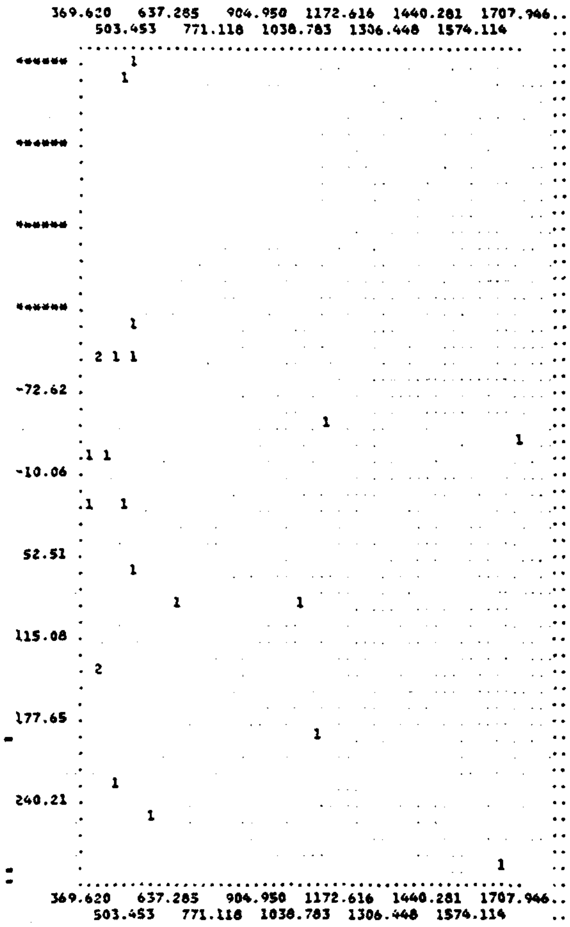
SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED		VARIABLE REMOVED	MULTIPLE R	MULTIPLE RSQ	INCREASE IN RSQ	F VALUE TO ENTER OR REMOVE
1	NDEV	2		0.9525	0.9072	0.9072	205.2752
2	NRAM	25		0.9775	0.9555	0.0483	21.6947

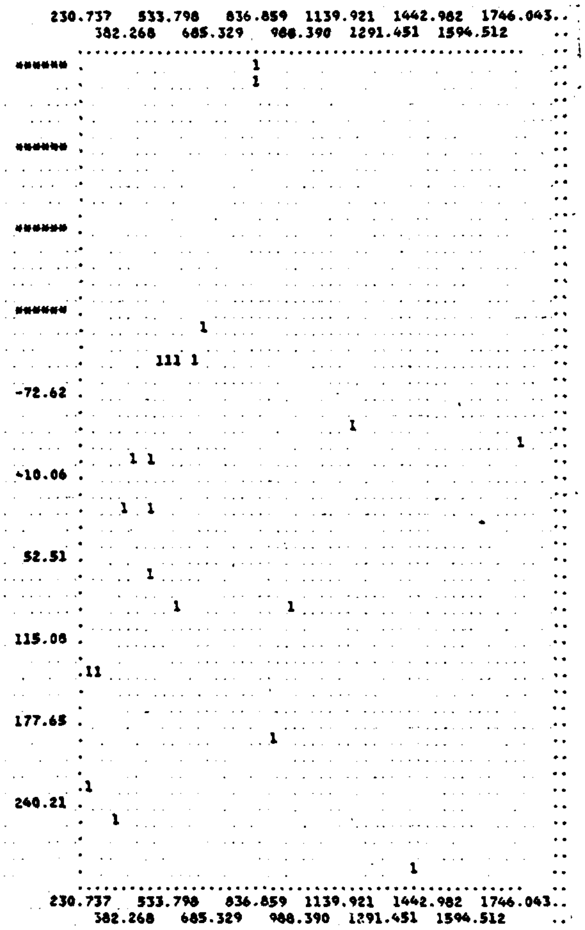
LIST OF RESIDUALS

CASE NUMBER	Y X(1)	Y COMPUTED	RESIDUAL	X(2)	X(25)
1	1103.4700	1146.8674	-43.3975	82.0000	24.0000
2	369.6201	396.3943	-26.7742	67.0000	0.0
3	1022.4399	932.2078	90.2322	83.0000	16.0000
4	399.3101	496.9722	-97.6621	84.0000	0.0
5	560.0601	307.6494	252.4106	52.0000	0.0
6	480.2400	792.7888	-312.5488	134.0000	0.0
7	379.7000	366.8127	12.8872	62.0000	0.0
8	509.3799	449.6414	59.7385	76.0000	0.0
9	475.6201	455.5579	20.0623	77.0000	0.0
10	415.9700	443.7251	-27.7551	75.0000	0.0
11	386.0901	242.5698	143.5203	41.0000	0.0
12	446.2700	548.2092	-101.9392	88.0000	1.0000
13	629.5400	544.3027	85.2373	92.0000	0.0
14	504.1799	627.1316	-122.9517	106.0000	0.0
15	491.4500	591.5205	-100.0706	86.0000	3.0000
16	493.5601	816.4543	-322.8943	138.0000	0.0
17	392.8201	485.1394	-92.3193	82.0000	0.0
18	390.5901	248.4861	142.1040	42.0000	0.0
19	461.0100	230.7371	230.2729	39.0000	0.0
20	1681.1799	1715.7373	-34.5574	290.0000	0.0
21	1072.8601	881.5339	191.3262	149.0000	0.0
22	1627.3601	1337.0918	290.2683	226.0000	0.0

PLOT OF RESIDUALS (Y-AXIS)
VS. VARIABLE 1 (X-AXIS)



PLOT OF RESIDUALS (Y-AXIS)
VS. COMPUTED Y (X-AXIS)



REGRESSION ANALYSIS RESULTS FOR CARD TEST HOURS (H)

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LABELS   1H          2P*NDG     3I-W        4NLG        5RA*NMC    6%MC**2
(F4.2,1X,F7.3,1X,F2.2,1X,F5.2,1X,F3.0,4X,F4.4)
  64    19370 05          31     2275
 237    18200 12 13250    43     1094
  97    26044 03          37     2961
  79    56274 01          46     3072
 198   133600 07   1000   32     1916
  64    15990 04          42     2623
 234     2208 71   4550   12     0076
 252     2320 80   5600   17     0034
 119    80127 07    075   45     2675
 127    12348 41   4075   20     0185
 154    28552 51          31     1299
 124   135675 06          28     1394
 274    49179 38          48     2348
 103    44581 15          49     2021
 356    97125 56    350   42     1600
 718    31920 74          42     1357
 761      480 98   1000   20     0225
 920    40386 73  19250   37     1218
 109    50505 78          49     1949
 130   200592 01          44     2744
 109    39592 04          50     2603
 108   145848 01   9250   53     2017
 101   139997 07   1275   44     0947
 602   260163  0         127     0955
1218  1208880 26         144     4174
  79   103238 11          42     2623
 343    71022 04          49     3031
 100    45540 08   4900   24     1159
```

VARIABLE		MEAN	STANDARD DEVIATION
H	1	2.77857	2.94451
P*NDG	2	109.27690	224.65331
1-W	3	0.27929	0.31301
NLG	4	23.06250	46.31536
RA*NMC	5	44.57143	28.05473
%MC**2	6	0.18062	0.10355

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6
1	1.000	0.598	0.445	0.234	0.531	0.006
2		1.000	-0.149	-0.144	0.804	0.477
3			1.000	0.225	-0.238	-0.560
4				1.000	-0.180	-0.378
5					1.000	0.484
6						1.000

SUB-PROBLEM 1

DEPENDENT VARIABLE	1
MAXIMUM NUMBER OF STEPS	12
F-LEVEL FOR INCLUSION	0.010000
F-LEVEL FOR DELETION	0.005000
TOLERANCE LEVEL	0.001000

STEP NUMBER 1
VARIABLE ENTERED 2

MULTIPLE R 0.5981
STD. ERROR OF EST. 2.4047

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	1	83.741	83.741	14.481
RESIDUAL	26	150.353	5.783	

VARIABLES IN EQUATION					VARIABLES NOT IN EQUATION			
VARIABLE	COEFFICIENT	STD. ERROR	F TO REMOVE		VARIABLE	PARTIAL CORR.	TOLERANCE	F TO ENTER
(CONSTANT	1.92192)							
P*NDG 2	0.00784	0.00206	14.4810 (2)		1-W 3	0.67387	0.9777	20.7956 (2)
					NLG 4	0.40332	0.9793	4.8567 (2)
					RA*NMC 5	0.10612	0.3540	0.2047 (1)
					XMC**2 6	-0.39675	0.7728	4.6705 (2)

STEP NUMBER 2
VARIABLE ENTERED 3

MULTIPLE R 0.8053
STD. ERROR OF EST. 1.8119

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	2	152.016	76.008	23.151
RESIDUAL	25	82.078	3.283	

VARIABLES IN EQUATION					VARIABLES NOT IN EQUATION			
VARIABLE	COEFFICIENT	STD. ERROR	F TO REMOVE		VARIABLE	PARTIAL CORR.	TOLERANCE	F TO ENTER
(CONSTANT	0.37316)							
P*NDG 2	0.00891	0.00157	32.2028 (2)		NLG 4	0.36399	0.9369	3.6653 (2)
1-W 3	5.13785	1.12667	20.7957 (2)		RA*NMC 5	0.42231	0.3250	5.2094 (1)
					XMC**2 6	-0.02929	0.5286	0.0206 (2)

STEP NUMBER 3
VARIABLE ENTERED 4

MULTIPLE R 0.8342
STD. ERROR OF EST. 1.7225

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	3	162.890	54.297	18.301
RESIDUAL	24	71.204	2.967	

VARIABLES IN EQUATION					VARIABLES NOT IN EQUATION			
VARIABLE	COEFFICIENT	STD. ERROR	F TO REMOVE		VARIABLE	PARTIAL CORR.	TOLERANCE	F TO ENTER
(CONSTANT	0.12963)							
P*NDG 2	0.00924	0.00150	37.8147 (2)		RA*NMC 5	0.47473	0.3241	6.6917 (1)
1-W 3	4.70147	1.09501	18.4344 (2)		XMC**2 6	0.08783	0.4825	0.1788 (2)
NLG 4	0.01416	0.00739	3.6653 (2)					

STEP NUMBER 4
VARIABLE ENTERED 6

MULTIPLE R 0.8355
STD. ERROR OF EST. 1.7527

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	4	163.439	40.860	13.301
RESIDUAL	23	70.655	3.072	

VARIABLES IN EQUATION					VARIABLES NOT IN EQUATION			
VARIABLE	COEFFICIENT	STD. ERROR	F TO REMOVE		VARIABLE	PARTIAL CORR.	TOLERANCE	F TO ENTER
(CONSTANT	-0.29669)							
P*NDG 2	0.00889	0.00173	26.3555 (2)		RA*NMC 5	0.47439	0.3233	6.3887 (1)
1-W 3	4.99903	1.31789	14.3387 (2)					
NLG 4	0.01514	0.00733	3.6953 (2)					
XMC**2 6	1.93307	4.68953	0.1789 (2)					

F-LEVEL OR TOLERANCE INSUFFICIENT FOR FURTHER COMPUTATION

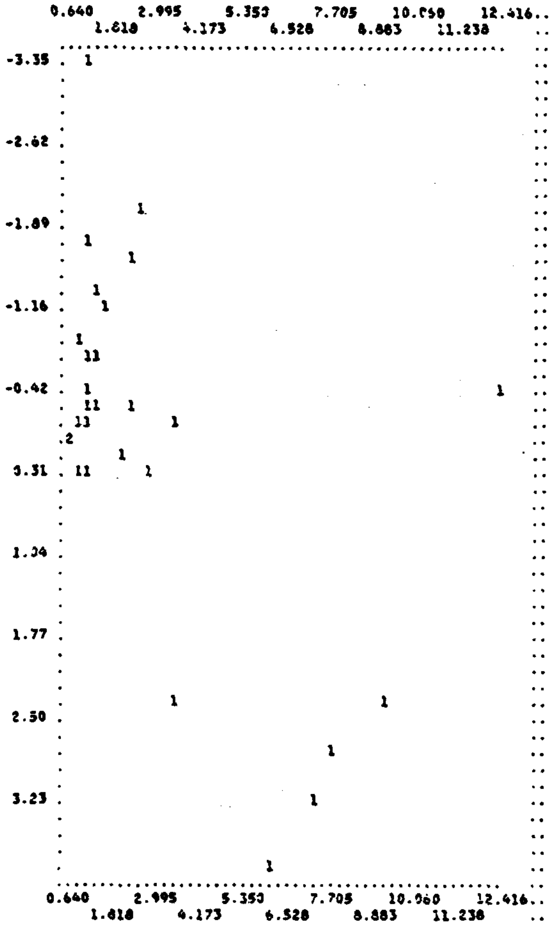
SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED		VARIABLE REMOVED	MULTIPLE R	RSQ	INCREASE IN RSQ	F VALUE TO ENTER OR REMOVE
1	R-NDG	2		0.5981	0.3577	0.3577	14.4810
2	1-W	3		0.8053	0.6494	0.2917	20.7957
3	NLG	4		0.8342	0.6958	0.0465	3.6653
4	IMC**2	6		0.8356	0.6982	0.0023	0.1788

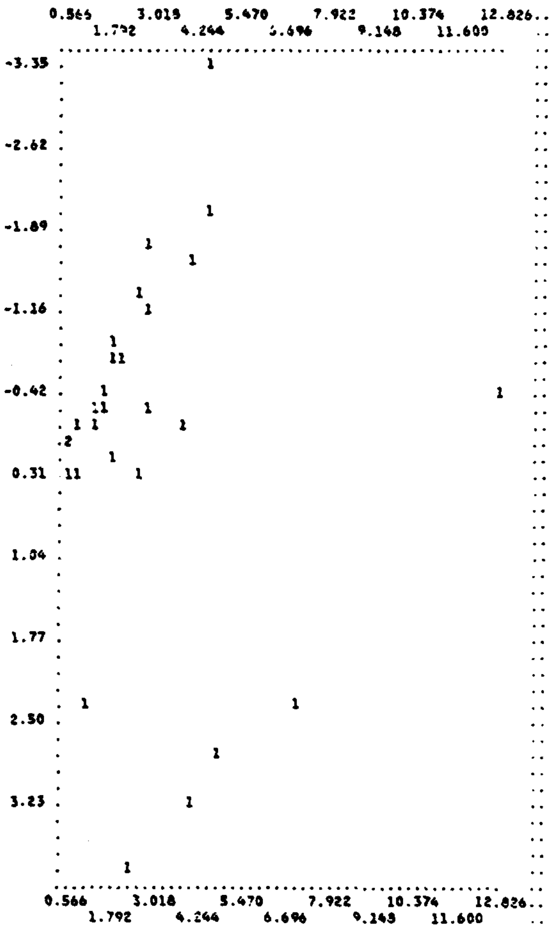
LIST OF RESIDUALS

CASE NUMBER	Y X(1)	Y COMPUTED	RESIDUAL	X(2)	X(3)	X(4)	X(6)
1	0.6400	0.5767	0.0633	19.3700	0.0500	0.0	0.2275
2	2.3700	2.6879	-0.3179	13.2000	0.1200	132.5000	0.1094
3	0.9700	0.6721	0.2979	25.0440	0.0300	0.0	0.2961
4	0.7900	0.8629	-0.0729	56.2740	0.0100	0.0	0.3072
5	1.9800	1.7726	0.2074	133.6000	0.0700	10.0000	0.1916
6	0.6400	0.5656	0.0744	15.9900	0.0400	0.0	0.2623
7	2.3400	3.9762	-1.6362	2.2050	0.7100	45.5000	0.0076
8	2.5200	4.5777	-2.0577	2.3200	0.6000	56.0000	0.0034
9	1.1900	1.3076	-0.1176	30.1270	0.0700	0.7500	0.2675
10	1.2700	2.5163	-1.2463	12.3480	0.4100	40.7500	0.0185
11	1.5400	2.7643	-1.2243	28.5520	0.5100	0.0	0.1299
12	1.2400	1.4862	-0.2462	135.6750	0.0600	0.0	0.1394
13	2.7400	2.5059	0.2341	49.1790	0.3800	0.0	0.2348
14	1.0300	1.2504	-0.2204	44.5810	0.1500	0.0	0.2021
15	3.5600	3.7368	-0.1768	97.1250	0.5600	3.5000	0.1600
16	7.1800	3.9556	3.2244	31.9200	0.7400	0.0	0.1357
17	7.6100	4.8027	2.8073	0.4830	0.9800	10.0000	0.0225
18	9.2000	6.8676	2.3324	40.3860	0.7300	192.5000	0.1218
19	1.0900	4.4382	-3.3482	50.3050	0.7800	0.0	0.1949
20	1.3000	2.0812	-0.7812	200.5920	0.0100	0.0	0.2744
21	1.0900	0.7715	0.3185	39.5920	0.0400	0.0	0.2603
22	1.0800	2.8506	-1.7706	145.8480	0.0100	92.5000	0.2017
23	1.0100	1.6790	-0.6690	139.9970	0.0700	12.7500	0.0947
24	6.0200	2.2062	3.8138	260.1631	0.0	0.0	0.0955
25	12.1800	12.5808	-0.4008	1208.8799	0.2600	0.0	0.4174
26	0.7900	1.6914	-0.9014	103.2380	0.1100	0.0	0.2623
27	3.4300	1.1359	2.2941	71.0220	0.3400	0.0	0.3031
28	1.0000	1.4799	-0.4799	45.5400	0.6800	49.0000	0.1159

PLOT OF RESIDUALS (Y-AXIS)
VS. VARIABLE 1 (X-AXIS)



PLOT OF RESIDUALS (Y-AXIS)
VS. COMPUTED Y (X-AXIS)



REGRESSION ANALYSIS RESULTS FOR CARD TEST YIELD (Yc)

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LABELS   1LOGYC    2MC/DEV   3QB2      4NLG       51-W      6YC
(F7.4,1X,F4.4,1X,F3.0,1X,F5.2,1X,F2.2)
-0.0362 4769  31        05
-0.3372 3308  43 13250 12
-0.3665 5542  46        01
-0.2518 1415  74  9900 18
-0.2924 4865 144        03
-0.3010 4651   5        65
-0.0605 5968            02
-0.0915 3359  31        01
-0.1487 5250            02
-0.0809 4643   4        03
-0.0362 5055            07
-0.1249 5208   5        03
-0.0555 4909            13
-0.1249 5000            02
-0.0809 3209   2   525 63
-0.0809 5921            13
-0.0655 5581   3        01
-0.3768 6667            27
-0.1135 4909            53
```

VARIABLE		MEAN	STANDARD DEVIATION
LOGYC	1	-0.15925	0.19700
MC/DEV	2	0.47489	0.48912
QB2	3	20.42105	41.15312
NLG	4	12.46053	37.96454
1-W	5	0.15474	0.25807
YC	6	0.71634	0.73649

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6
1	1.000	-0.777	-0.642	-0.493	-0.562	-0.650
2		1.000	0.404	0.169	0.542	0.949
3			1.000	0.439	0.148	0.385
4				1.000	0.199	0.227
5					1.000	0.551
6						1.000

SUB-PROBLM 1

DEPENDENT VARIABLE	1
MAXIMUM NUMBER OF STEPS	12
F-LEVEL FOR INCLUSION	0.010000
F-LEVEL FOR DELETION	0.005000
TOLERANCE LEVEL	0.001000

STEP NUMBER 1
VARIABLE ENTERED 2

MULTIPLE R 0.7771
STD. ERROR OF EST. 0.1274

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	1	0.445	0.445	27.440
RESIDUAL	18	0.292	0.016	

VARIABLES IN EQUATION

VARIABLE	COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT	0.0)		
MC/DEV 2	-0.31298	0.05975	27.4397 (2)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
QB2	3	-0.56944	0.8367	8.2576 (2)
NLG	4	-0.58309	0.9715	8.7574 (2)
1-W	5	-0.26641	0.7058	1.2988 (2)
YC	6	0.44278	0.0989	4.1456 (1)

STEP NUMBER 2
VARIABLE ENTERED 4

MULTIPLE R 0.8594
STD. ERROR OF EST. 0.1065

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	2	0.545	0.272	24.011
RESIDUAL	17	0.193	0.011	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
MC/DEV	2	-0.28768	0.05067	32.2294 (2)
NLG	4	-0.00193	0.00065	8.7574 (2)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
QB2	3	-0.44507	0.6951	3.9523 (2)
1-W	5	-0.23685	0.6939	0.9509 (2)
YC	6	0.71756	0.0942	16.9827 (1)

STEP NUMBER 3
VARIABLE ENTERED 3

MULTIPLE R 0.8890
STD. ERROR OF EST. 0.0983

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	3	0.583	0.194	20.105
RESIDUAL	16	0.155	0.010	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
MC/DEV	2	-0.25034	0.05041	24.6656 (2)
QB2	3	-0.00131	0.00066	3.9523 (2)
NLG	4	-0.00139	0.00066	4.4280 (2)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
1-W	5	-0.34910	0.6759	2.0018 (2)
YC	6	0.75818	0.0934	20.2800 (1)

STEP NUMBER 4
VARIABLE ENTERED 5

MULTIPLE R 0.9033
STD. ERROR OF EST. 0.0951

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	4	0.602	0.150	16.619
RESIDUAL	15	0.136	0.009	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
MC/DEV	2	-0.20504	0.05801	12.4917 (2)
QB2	3	-0.00146	0.00064	5.1064 (2)
NLG	4	-0.00122	0.00065	3.4982 (2)
1-W	5	-0.14042	0.10267	2.0018 (2)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
YC	6	0.84935	0.0925	36.2492 (1)

F-LEVEL OR TOLERANCE INSUFFICIENT FOR FURTHER COMPUTATION

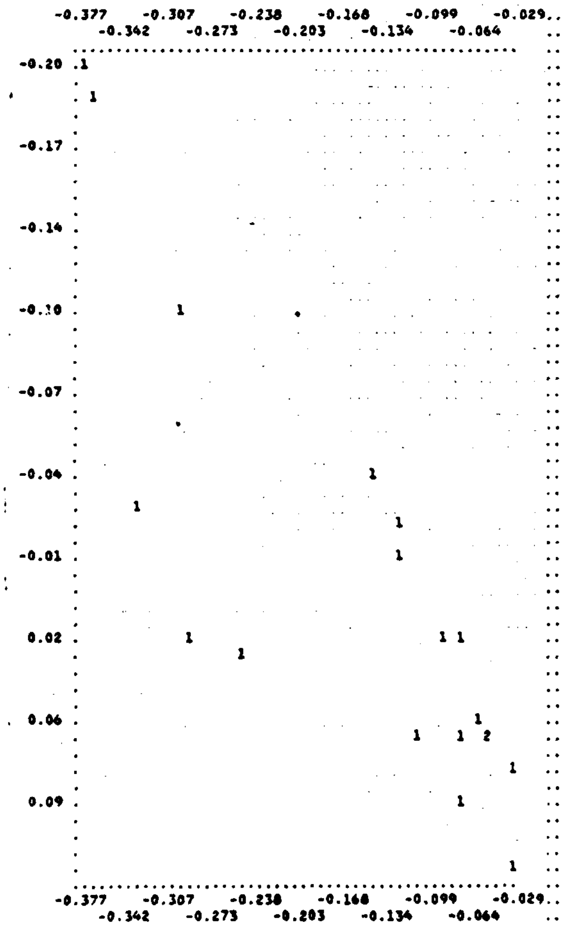
SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED		VARIABLE REMOVED	MULTIPLE R	RSQ	INCREASE IN RSQ	F VALUE TO ENTER OR REMOVE
1	MC/DEV	2		0.7771	0.6039	0.6039	27.4397
2	NLG	4		0.8594	0.7386	0.1347	8.7574
3	Q32	3		0.8890	0.7903	0.0516	3.9523
4	1-W	5		0.9033	0.8159	0.0256	2.0018

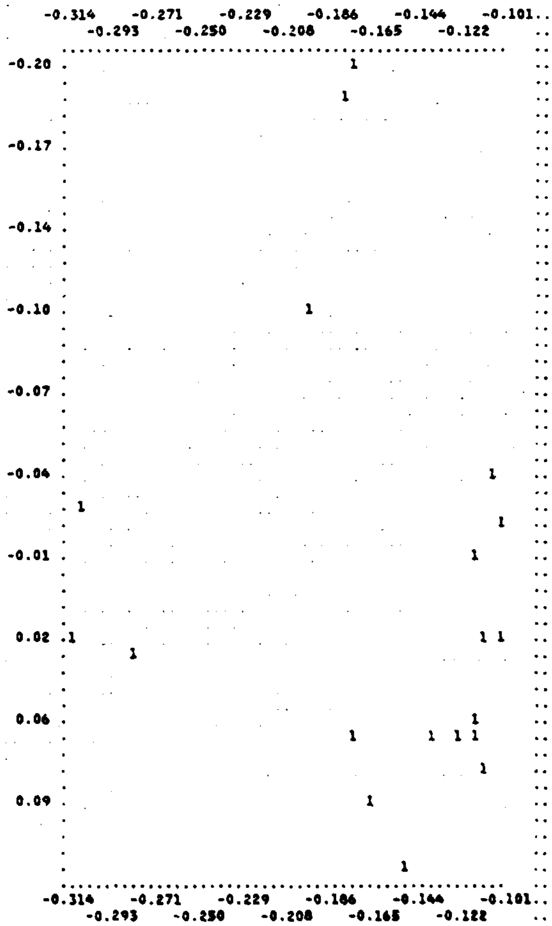
LIST OF RESIDUALS

CASE NUMBER	Y X(1)	Y COMPUTED	RESIDUAL	X(2)	X(4)	X(3)	X(5)
1	-0.0362	-0.1504	0.1142	0.4769	0.0	31.0000	0.0500
2	-0.3372	-0.3096	-0.0276	0.3308	132.5000	43.0000	0.1200
3	-0.3665	-0.1821	-0.1844	0.5542	0.0	46.0000	0.0100
4	-0.2518	-0.2841	0.0323	0.1415	99.0000	74.0000	0.1800
5	-0.2924	-0.3139	0.0215	0.4865	0.0	144.0000	0.0300
6	-0.3010	-0.1991	-0.1019	0.4651	0.0	5.0000	0.6500
7	-0.0605	-0.1253	0.0648	0.5968	0.0	0.0	0.0200
8	-0.0915	-0.1153	0.0240	0.3359	0.0	31.0000	0.0100
9	-0.1487	-0.1106	-0.0381	0.5250	0.0	0.0	0.0200
10	-0.0809	-0.1055	0.0246	0.4643	0.0	4.0000	0.0300
11	-0.0362	-0.1140	0.0778	.5055	0.0	0.0	0.0700
12	-0.1249	-0.1185	-0.0064	0.5208	0.0	5.0000	0.0300
13	-0.0555	-0.1199	0.0644	0.4909	0.0	0.0	0.1300
14	-0.1249	-0.1055	-0.0194	0.5000	0.0	0.0	0.0200
15	-0.0809	-0.1686	0.0877	0.3209	5.2500	2.0000	0.6300
16	-0.0809	-0.1407	0.0598	0.5921	0.0	0.0	0.1300
17	-0.0655	-0.1203	0.0548	0.5581	0.0	3.0000	0.0100
18	-0.3768	-0.1768	-0.2000	0.6667	0.0	0.0	0.2700
19	-0.1135	-0.1793	0.0658	0.4909	0.0	0.0	0.5300

PLOT OF RESIDUALS (Y-AXIS)
VS. VARIABLE 1 (X-AXIS)



PLOT OF RESIDUALS (Y-AXIS)
VS. COMPUTED Y (X-AXIS)



REGRESSION ANALYSIS RESULTS FOR SYSTEM TEST YIELD (Ys)

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LABELS  1YS      2NDEV     3NMC      4QA       5QB       6QB1      7QB2
0
LABELS  12TTLDTL  13ECL    14MOS     15IIL     18DIGLSI  19BIPMEM  20PINS
0
LABELS  21NDG     22NLG    23BITS    24NROM    25NRAM    26MC/DEV  27%MC**2
0
LABELS  38RA      39LNYS
0
(7X,F5.2,2X,18F3.0,2F6.0,F6.2,F6.0,2F3.0)
```

96	149	9	0	0	9	0	0	0	0	0	0	9	0	0	0	9	0	0	0	0	3750	0	0	0
94	81	51	0	0	51	0	0	0	0	0	51	0	0	0	51	0	0	0	714	449	0	0	0	0
87	129	19	0	0	19	0	0	0	0	0	19	0	0	0	19	0	0	0	266	173	0	0	0	0
74	73	56	0	0	56	0	0	0	0	0	56	0	0	0	56	0	0	0	784	308	0	0	0	0
91	64	51	0	0	51	0	0	0	0	0	51	0	0	0	51	0	0	0	714	270	0	0	0	0
93	128	7	0	0	7	0	0	0	0	0	5	2	0	0	5	2	0	0	70	48	975	0	0	0
81	54	37	0	0	37	0	0	0	0	0	37	0	0	0	37	0	0	0	522	184	0	0	0	0
94	30	20	0	0	20	0	0	0	0	0	20	0	0	0	20	0	0	0	296	106	0	0	0	0
89	40	26	0	0	26	0	0	0	0	0	26	0	0	0	26	0	0	0	364	238	0	0	0	0
95	137	7	0	0	7	0	0	0	0	0	1	6	0	0	1	6	0	0	14	6	3525	0	0	0
72	153	3	0	0	3	0	0	0	0	0	1	2	0	0	1	2	0	0	14	4	975	0	0	0
96	73	58	0	0	58	0	0	0	0	0	58	0	0	0	58	0	0	0	816	397	0	0	0	0
89	73	54	0	0	54	0	0	0	0	0	54	0	0	0	54	0	0	0	756	446	0	0	0	0
91	54	44	0	0	44	0	0	0	0	0	44	0	0	0	44	0	0	0	616	242	0	0	0	0
91	59	41	0	0	41	0	0	0	0	0	41	0	0	0	41	0	0	0	582	146	0	0	0	0
89	58	47	0	0	47	0	0	0	0	0	47	0	0	0	47	0	0	0	660	319	0	0	0	0
91	68	28	0	0	28	0	0	0	0	0	28	0	0	0	8	0	0	20	446	32	0	5120	20	0
93	66	26	0	0	26	0	0	0	0	0	26	0	0	0	8	0	0	18	407	32	0	4608	18	0
93	63	23	0	0	23	0	0	0	0	0	23	0	0	0	8	0	0	15	352	32	0	3840	15	0
98	36	28	0	0	28	0	0	0	0	0	28	0	0	0	28	0	0	0	408	261	0	0	0	0
83	160	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	550	0	0	0
96	67	53	0	0	53	0	0	0	0	0	53	0	0	0	53	0	0	0	742	300	0	0	0	0

VARIABLE		MEAN	STANDARD DEVIATION
YS	1	0.89818	0.90066
NDEV	2	82.50000	91.34326
NMC	3	31.31818	36.31992
QA	4	0.0	0.0
QB	5	0.0	0.0
QB1	6	31.31818	36.31992
QB2	7	0.0	0.0
	8	0.0	0.0
	9	0.0	0.0
	10	0.0	0.0
	11	0.0	0.0

TTLDTL	12	30.40909	34.21840
ECL	13	0.90909	2.39317
MCS	14	0.0	0.0
IIL	15	0.0	0.0
	16	28.00000	35.07265
	17	0.90909	2.39317
DIGLSI	18	0.0	0.0
BIPMEM	19	2.40909	6.56783
PINS	20	433.77271	513.43579
NDG	21	181.50000	233.81665
NLG	22	4.44318	11.42005
BITS	23	616.72705	1681.36377
NROM	24	2.40909	6.56783
NRAM	25	0.0	0.0
MC/DEV	26	0.50585	0.59001
%MC**2	27	0.34811	0.43353
	28	0.0	0.0
	29	0.0	0.0
	30	93.95454	108.95975
	31	0.0	0.0
	32	0.0	0.0
	33	93.95454	108.95975
	34	93.95454	108.95975
	35	0.0	0.0
	36	31.31818	36.31992
	37	31.31818	36.31992
RA	38	3.00000	3.00000
LNYS	39	-0.11037	0.13566

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10
1	1.000	0.892	0.863	0.0	0.0	0.863	0.0	0.0	0.0	0.0
2		1.000	0.640	0.0	0.0	0.640	0.0	0.0	0.0	0.0
3			1.000	0.0	0.0	1.000	0.0	0.0	0.0	0.0
4				0.0	0.0	0.0	0.0	0.0	0.0	0.0
5					0.0	0.0	0.0	0.0	0.0	0.0
6						1.000	0.0	0.0	0.0	0.0
7							0.0	0.0	0.0	0.0
8								0.0	0.0	0.0
9									0.0	0.0
10										0.0

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19	20
1	0.0	0.840	0.390	0.0	0.0	0.797	0.390	0.0	0.376	0.846
2	0.0	0.602	0.600	0.0	0.0	0.572	0.600	0.0	0.268	0.605
3	0.0	0.998	0.075	0.0	0.0	0.981	0.075	0.0	0.262	0.997
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.998	0.075	0.0	0.0	0.981	0.075	0.0	0.262	0.997
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12		1.000	0.009	0.0	0.0	0.904	0.009	0.0	0.262	1.000
13			1.000	0.0	0.0	0.010	1.000	0.0	0.0	0.009
14				0.0	0.0	0.0	0.0	0.0	0.0	0.0
15					0.0	0.0	0.0	0.0	0.0	0.0
16						1.000	0.010	0.0	0.084	0.978
17							1.000	0.0	0.0	0.009
18								0.0	0.0	0.0
19									1.000	0.290
20										1.000

VARIABLE NUMBER	21	22	23	24	25	26	27	28	29	30
1	0.779	0.398	0.376	0.376	0.0	0.861	0.806	0.0	0.0	0.863
2	0.567	0.612	0.265	0.265	0.0	0.581	0.525	0.0	0.0	0.640
3	0.948	0.075	0.262	0.262	0.0	0.971	0.956	0.0	0.0	1.000
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.948	0.075	0.262	0.262	0.0	0.971	0.956	0.0	0.0	1.000
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.950	0.010	0.262	0.262	0.0	0.972	0.959	0.0	0.0	0.998
13	0.011	0.987	0.0	0.0	0.0	0.032	0.002	0.0	0.0	0.075
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.972	0.011	0.084	0.084	0.0	0.958	0.966	0.0	0.0	0.981
17	0.011	0.987	0.0	0.0	0.0	0.032	0.002	0.0	0.0	0.075
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.050	0.0	1.000	1.000	0.0	0.244	0.131	0.0	0.0	0.262
20	0.943	0.010	0.290	0.290	0.0	0.972	0.956	0.0	0.0	0.997
21	1.000	0.012	0.050	0.050	0.0	0.921	0.926	0.0	0.0	0.948
22		1.000	0.0	0.0	0.0	0.033	0.002	0.0	0.0	0.075
23			1.000	1.000	0.0	0.244	0.131	0.0	0.0	0.262
24				1.000	0.0	0.244	0.131	0.0	0.0	0.262
25					0.0	0.0	0.0	0.0	0.0	0.0
26						1.000	0.989	0.0	0.0	0.971
27							1.000	0.0	0.0	0.956
28								0.0	0.0	0.0
29									0.0	0.0
30										1.000

VARIABLE NUMBER	31	32	33	34	35	36	37	38	39
1	0.0	0.0	0.863	0.863	0.0	0.863	0.863	0.997	-0.768
2	0.0	0.0	0.640	0.640	0.0	0.640	0.640	0.903	-0.805
3	0.0	0.0	1.000	1.000	0.0	1.000	1.000	0.862	-0.674
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	1.000	1.000	0.0	1.000	1.000	0.862	-0.674
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.998	0.998	0.0	0.998	0.998	0.840	-0.660
13	0.0	0.0	0.075	0.075	0.0	0.075	0.075	0.380	-0.233
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.981	0.981	0.0	0.981	0.981	0.798	-0.641
17	0.0	0.0	0.075	0.075	0.0	0.075	0.075	0.380	-0.233
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.262	0.262	0.0	0.262	0.262	0.367	-0.218
20	0.0	0.0	0.997	0.997	0.0	0.997	0.997	0.845	-0.661
21	0.0	0.0	0.948	0.948	0.0	0.948	0.948	0.776	-0.595
22	0.0	0.0	0.075	0.075	0.0	0.075	0.075	0.389	-0.243
23	0.0	0.0	0.262	0.262	0.0	0.262	0.262	0.367	-0.218
24	0.0	0.0	0.262	0.262	0.0	0.262	0.262	0.367	-0.218
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.971	0.971	0.0	0.971	0.971	0.857	-0.648
27	0.0	0.0	0.956	0.956	0.0	0.956	0.956	0.803	-0.610
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	1.000	1.000	0.0	1.000	1.000	0.862	-0.674
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33			1.000	1.000	0.0	1.000	1.000	0.862	-0.674
34				1.000	0.0	1.000	1.000	0.862	-0.674
35					0.0	0.0	0.0	0.0	0.0
36						1.000	1.000	0.862	-0.674
37							1.000	0.862	-0.674
38								1.000	-0.814
39									1.000

SUB-PROBLM 1
DEPENDENT VARIABLE 39
MAXIMUM NUMBER OF STEPS 2
F-LEVEL FOR INCLUSION 0.010000
F-LEVEL FOR DELETION 0.005000
TOLERANCE LEVEL 0.001000

STEP NUMBER 1
VARIABLE ENTERED 2

MULTIPLE R 0.8051
STD. ERROR OF EST. 0.0824

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	1	0.262	0.262	38.702
RESIDUAL	21	0.142	0.007	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
NDEV	2	-0.00120	0.00019	38.7025 (9)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
YS	1	-0.18691	0.2045	0.7240 (1)
NMC	3	-0.34747	0.5904	2.7462 (9)
QA	4	0.0	0.0	0.0 (1)
QB	5	0.0	0.0	0.0 (1)
QB1	6	-0.34747	0.5904	2.7462 (1)
QB2	7	0.0	0.0	0.0 (1)
	8	0.0	0.0	0.0 (1)
	9	0.0	0.0	0.0 (1)
	10	0.0	0.0	0.0 (1)
	11	0.0	0.0	0.0 (1)
TTLDTL	12	-0.37025	0.6374	3.1778 (1)
ECL	13	0.52704	0.6401	7.6919 (1)
MOS	14	0.0	0.0	0.0 (2)
IIL	15	0.0	0.0	0.0 (1)
	16	-0.37019	0.6725	3.1773 (1)
	17	0.52704	0.6401	7.6919 (1)
DIBLSI	18	0.0	0.0	0.0 (1)
BIPMEM	19	-0.00928	0.9300	0.0017 (1)
PINS	20	-0.36809	0.6341	3.1346 (1)
NDG	21	-0.28461	0.6791	1.7628 (2)
NLG	22	0.53217	0.6259	7.9018 (2)
BITS	23	-0.00928	0.9300	0.0017 (1)
NROM	24	-0.00928	0.9300	0.0017 (1)
NRAM	25	0.0	0.0	0.0 (1)
MC/DEV	26	-0.37318	0.6623	3.2342 (2)
%MC**2	27	-0.37130	0.7239	3.1981 (2)
	28	0.0	0.0	0.0 (1)
	29	0.0	0.0	0.0 (1)
	30	-0.34747	0.5904	2.7463 (1)
	31	0.0	0.0	0.0 (1)
	32	0.0	0.0	0.0 (1)
	33	-0.34747	0.5904	2.7463 (1)
	34	-0.34747	0.5904	2.7463 (1)
	35	0.0	0.0	0.0 (1)
	36	-0.34747	0.5904	2.7462 (1)
	37	-0.34747	0.5904	2.7462 (1)
RA	38	-0.33927	0.1843	2.6015 (1)

STEP NUMBER 2
VARIABLE ENTERED 3

MULTIPLE R 0.8311
STD. ERROR OF EST. 0.0791

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO
REGRESSION	2	0.280	0.140	22.333
RESIDUAL	20	0.125	0.006	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE
(CONSTANT		0.0)		
NDEV	2	-0.00094	0.00024	15.3217 (9)
NMC	3	-0.00100	0.00060	2.7463 (9)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER
YS	1	0.20866	0.0596	0.8649 (1)
QA	4	0.0	0.0	0.0 (1)
QB	5	0.0	0.0	0.0 (1)
QB1	6	-0.00044	0.0000	0.0000 (1)
QB2	7	0.0	0.0	0.0 (1)
	8	0.0	0.0	0.0 (1)
	9	0.0	0.0	0.0 (1)
	10	0.0	0.0	0.0 (1)
	11	0.0	0.0	0.0 (1)
TTLDTL	12	-0.43485	0.0021	4.4306 (1)
ECL	13	0.43479	0.4786	4.4290 (1)
MOS	14	0.0	0.0	0.0 (1)
IIL	15	0.0	0.0	0.0 (1)
	16	-0.15251	0.0315	0.4524 (1)
	17	0.43479	0.4788	4.4290 (1)
DIGLSI	18	0.0	0.0	0.0 (1)
BIPMEM	19	0.03652	0.9155	0.0254 (1)
PINS	20	-0.31390	0.0034	2.0768 (1)
NDG	21	0.10270	0.0985	0.2025 (2)
NLG	22	0.43883	0.4566	4.5315 (2)
BITS	23	0.03652	0.9155	0.0254 (1)
NROM	24	0.03652	0.9155	0.0254 (1)
NRAM	25	0.0	0.0	0.0 (1)
MC/DEV	26	-0.14961	0.0544	0.4350 (2)
%MC**2	27	-0.14045	0.0728	0.3824 (2)
	28	0.0	0.0	0.0 (1)
	29	0.0	0.0	0.0 (1)
	30	0.0	0.0	0.0 (1)
	31	0.0	0.0	0.0 (1)
	32	0.0	0.0	0.0 (1)
	33	0.0	0.0	0.0 (1)
	34	0.0	0.0	0.0 (1)
	35	0.0	0.0	0.0 (1)
	36	-0.00044	0.0000	0.0000 (1)
	37	-0.00044	0.0000	0.0000 (1)
RA	38	-0.08372	0.0474	0.1341 (1)

SPECIFIED STEP REACHED

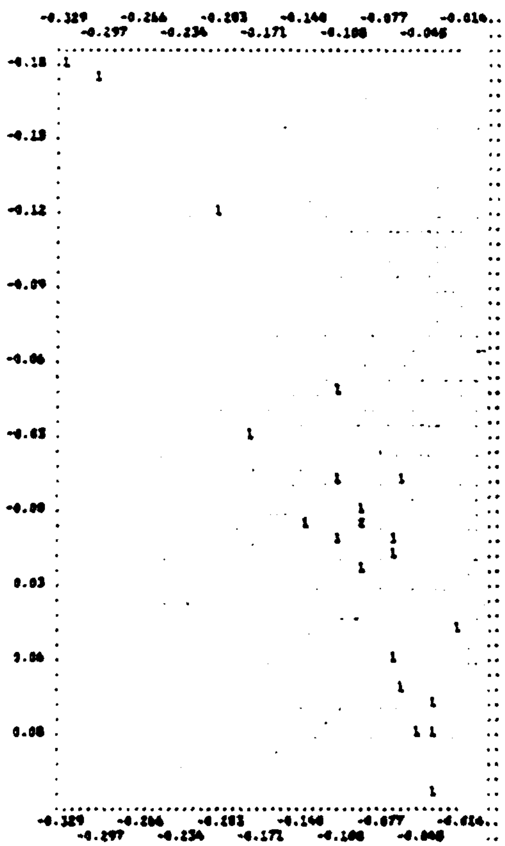
SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED		VARIABLE REMOVED	MULTIPLE R	RSQ	INCREASE IN RSQ	F VALUE TO ENTER OR REMOVE
1	NDEV	2		0.8051	0.6483	0.6483	38.7025
2	NMC	3		0.8311	0.6907	0.0425	2.7463

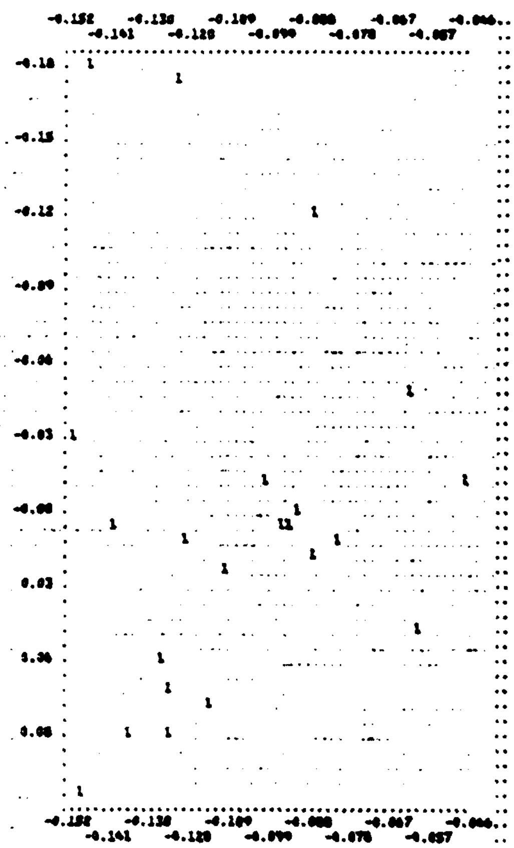
LIST OF RESIDUALS

CASE NUMBER	Y X(39)	Y COMPUTED	RESIDUAL	X(2)	X(3)
1	-0.0408	-0.1492	0.1084	149.0000	9.0000
2	-0.0619	-0.1273	0.0654	81.0000	51.0000
3	-0.1393	-0.1404	0.0011	129.0000	19.0000
4	-0.3011	-0.1248	-0.1763	73.0000	56.0000
5	-0.0943	-0.1113	0.0170	64.0000	51.0000
6	-0.0726	-0.1274	0.0549	128.0000	7.0000
7	-0.2107	-0.0879	-0.1228	54.0000	37.0000
8	-0.0619	-0.0483	-0.0136	30.0000	20.0000
9	-0.1165	-0.0637	-0.0529	40.0000	26.0000
10	-0.0513	-0.1359	0.0846	137.0000	7.0000
11	-0.3285	-0.1470	-0.1815	153.0000	3.0000
12	-0.0408	-0.1268	0.0860	73.0000	58.0000
13	-0.1165	-0.1228	0.0062	73.0000	54.0000
14	-0.0943	-0.0949	0.0006	54.0000	44.0000
15	-0.0943	-0.0966	0.0023	59.0000	41.0000
16	-0.1165	-0.1017	-0.0149	58.0000	47.0000
17	-0.0943	-0.0920	-0.0023	68.0000	28.0000
18	-0.0726	-0.0881	0.0156	66.0000	26.0000
19	-0.0726	-0.0823	0.0097	63.0000	23.0000
20	-0.0202	-0.0619	0.0417	36.0000	28.0000
21	-0.1063	-0.1515	-0.0348	160.0000	1.0000
22	-0.0408	-0.1161	0.0753	67.0000	53.0000

PLOT OF RESIDUALS (Y-AXIS)
VS. VARIABLE 39 (X-AXIS)



PLOT OF RESIDUALS (Y-AXIS)
VS. COMPUTED Y (X-AXIS)



Appendix B

Computer Program Documentation

This appendix describes the computer program documentation for the MC LCC model. Figure B-1 gives a general overview of the LCC model flow diagram and describes the order in which the major CER's for the LCC program occur.

A detailed flowchart is also provided which gives a complete description of the LCC programs. At each step (box) of the flowchart the following information is provided:

a) The line number in the source listing for which the step occurs (see page B-3).

b) The step (box) number found on the upper right hand side of the box is a reference number for continuation branches in the program.

c) In the continuation boxes, the number inside the box describes the page and box number for the next step. The page and box number are identified as follows:

Y.X

Where Y is the page number and X is the box number. The number on the lower right hand side of the box is the corresponding branch location to the source listing.

A source listing for the MC LCC program is provided following the detailed flow diagram. Comments describing what each section of the program executes are imbedded in the listing. All the CER's developed for the LCC model are provided as subroutines and are clearly marked in the listing.

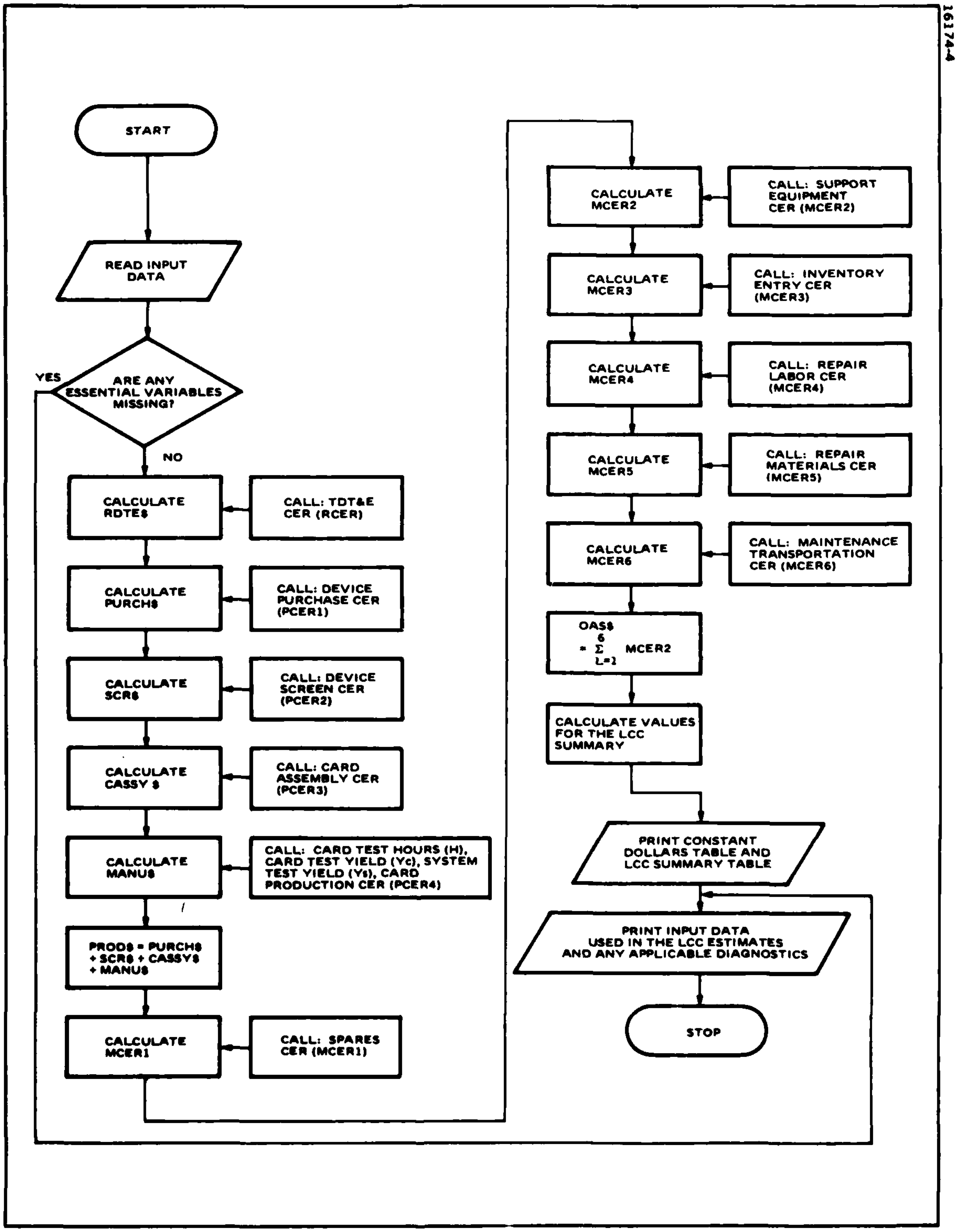
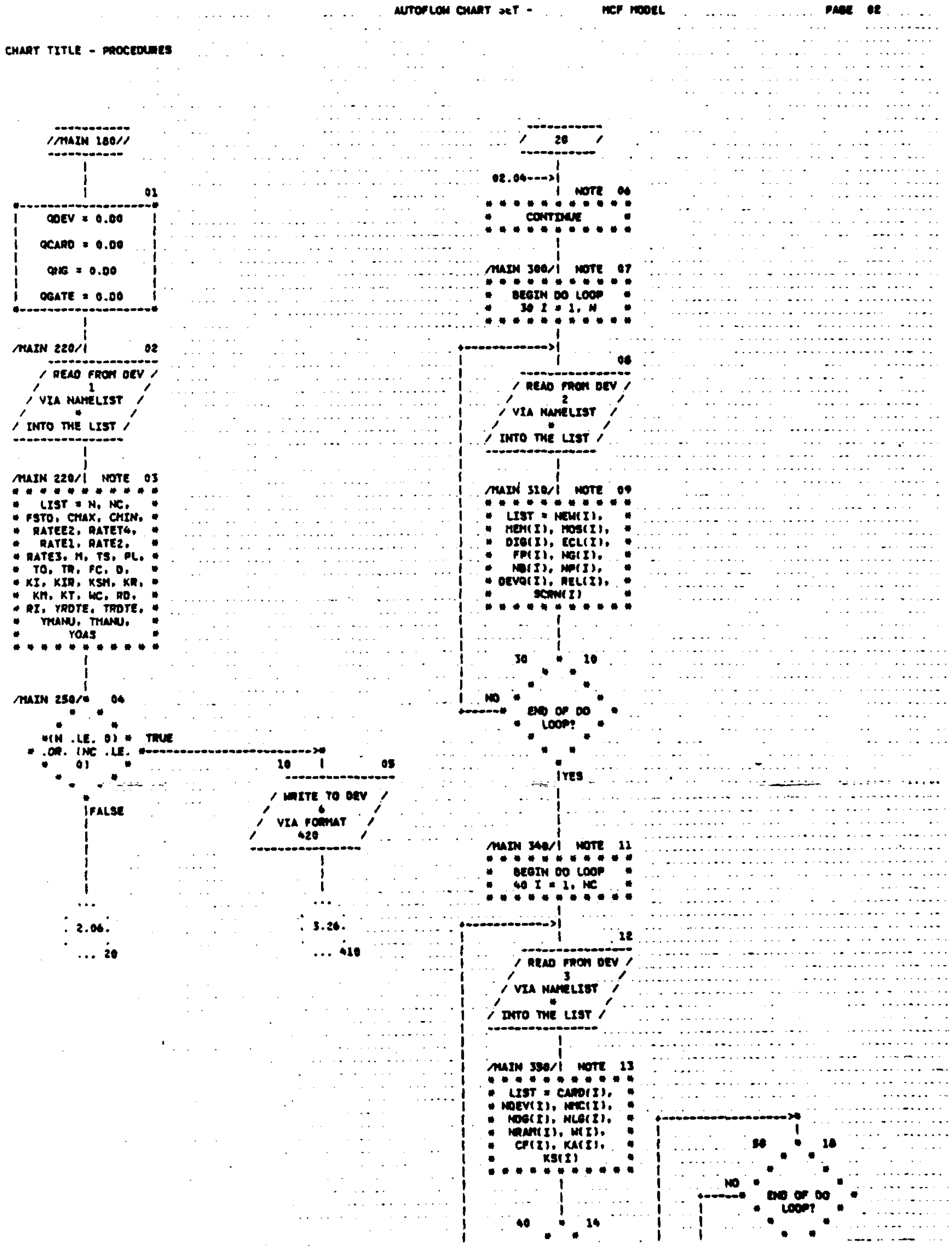
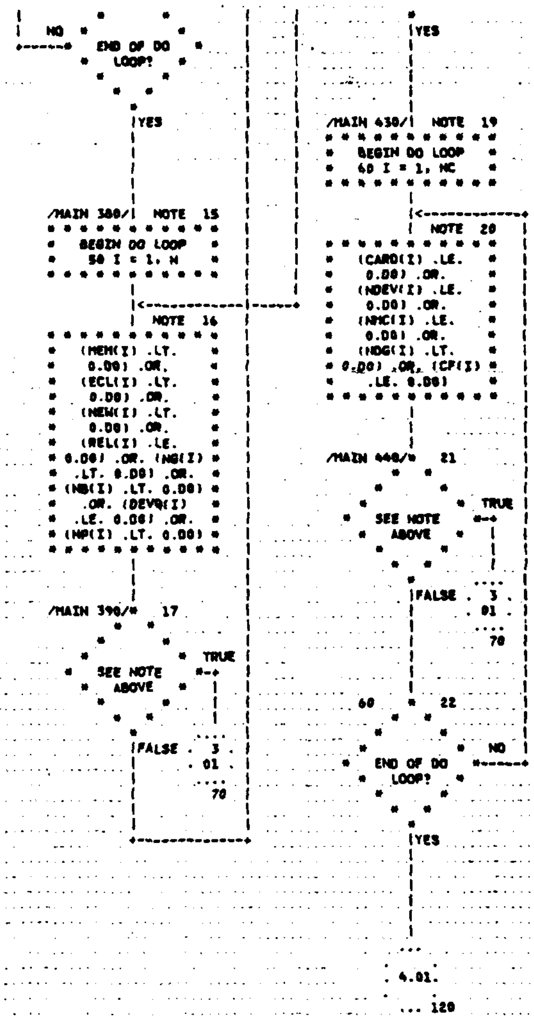


Figure B-1. Simplified Flowchart

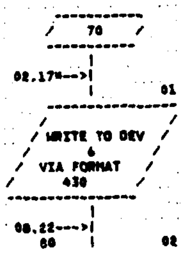
B.1 DETAILED FLOW DIAGRAM FOR THE LCC PROGRAM





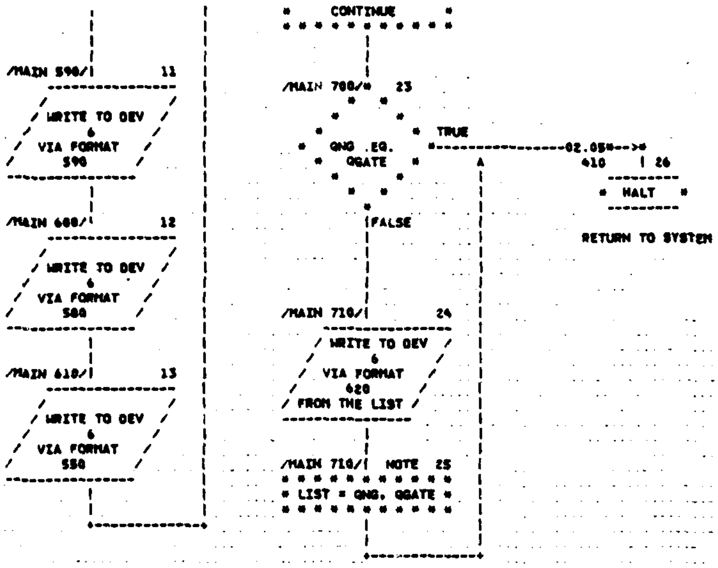
AUTOFLOW CHART SET - MCF MODEL PAGE 03

CHART TITLE - PROCEDURES



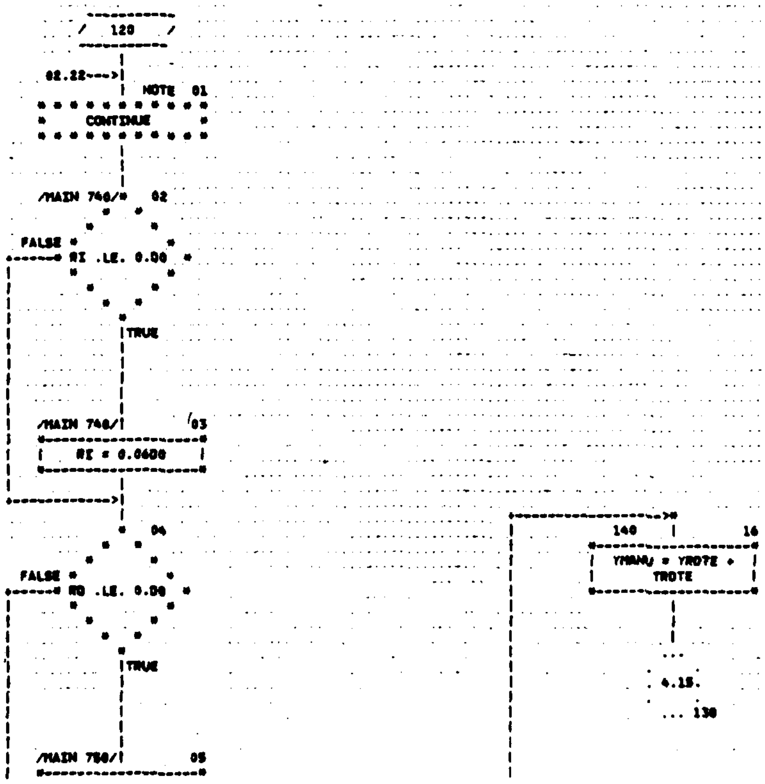
```
      /               /
     / WRITE TO DEV  /
    /       6       /
   /   VIA FORMAT  /
  /       500     /
  ----------------
          |
          |
/MAIN 500/|          03
      ----------------
     / WRITE TO DEV  /
    /       6       /
   /   VIA FORMAT  /
  /       520     /
 / FROM THE LIST /
 ----------------
          |
          |
/MAIN 500/|  NOTE  04
* * * * * * * * * * *
* LIST = N, M, KR,  *
* NC, TS, KM, FSTD, *
* PL, KT, CMAX, TO, *
* WC, CMIN, TR, 9D, *
*  RATEE2, FC, RI,  *
* RATET4, D, YROTE, *
* RATE1, KI, TROTE, *
*     RATE2, KIR,   *
*   YMANU, RATE3,   *
* KSM, THANU, YOAS  *
* * * * * * * * * * *
          |
          |
/MAIN 530/|          05
      ----------------
     /               /
    / WRITE TO DEV  /
   /       6       /
  /   VIA FORMAT  /
 /       570     /
 ----------------
          |
          |
/MAIN 540/|          06
      ----------------
     /               /
    / WRITE TO DEV  /
   /       6       /
  /   VIA FORMAT  /
 /       530     /
 ----------------
          |
          |
/MAIN 550/|  NOTE  07
* * * * * * * * * * *
*   BEGIN DO LOOP   *
*     90 I = 1, N   *
* * * * * * * * * * *
          |
+------------>|
|             |          08
|       ----------------
|      / WRITE TO DEV  /
|     /       6       /
|    /   VIA FORMAT  /
|   /       540     /
|  / FROM THE LIST /
|  ----------------
|             |
|             |
|  /MAIN 560/|  NOTE  09
|  * * * * * * * * * * *
|  * LIST = I, NEW(I), *
|  *  MEM(I), MOS(I),  *
|  *  OIG(I), ECL(I),  *
|  *    FP(I), NG(I),  *
|  *    NB(I), NP(I),  *
|  * DEVQ(I), REL(I),  *
|  *      SCRN(I)      *
|  * * * * * * * * * * *
|             |
|             |
|       90    *    10
|           *   *
|         *       *
|  NO   *           *
+------*  END OF DO   *
        *   LOOP?   *
          *       *
            *   *
              *
              |YES
              |
```

```
+------------------>*
|   /MAIN 620/|  NOTE  14
|   * * * * * * * * * * *
|   *   BEGIN DO LOOP   *
|   *   100 I = 1, NC   *
|   * * * * * * * * * * *
|             |
|  +--------->|
|  |          |           15
|  |     ----------------
|  |    / WRITE TO DEV  /
|  |   /       6       /
|  |  /   VIA FORMAT  /
|  | /       560     /
|  |/ FROM THE LIST /
|  |----------------
|  |          |
|  |          |
|  |/MAIN 630/|  NOTE  16
|  |* * * * * * * * * * *
|  |*      LIST = I,     *
|  |* CARD(I), NDEV(I), *
|  |*   NMC(I), QA(I),  *
|  |*   QB(I), QB1(I),  *
|  |*   QB2(I), QCD(I), *
|  |*   NDG(I), NLG(I), *
|  |*   NRAM(I), W(I),  *
|  |*    CF(I), KA(I),  *
|  |*       KS(I)       *
|  |* * * * * * * * * * *
|  |          |
|  |          |
|  |    100   *   17
|  |        *   *
|  |      *       *
|  | NO *           *
|  +---*  END OF DO   *
|       *   LOOP?   *
|         *       *
|           *   *
|             *
|             |YES
|             |
|             |
|   /MAIN 660/|           18
|        ----------------
|       /               /
|      / WRITE TO DEV  /
|     /       6       /
|    /   VIA FORMAT  /
|   /       600     /
|   ----------------
|             |
|             |
|   /MAIN 670/*   19
|           *   *
|         *       *
|  TRUE *           *
|  +---*  QCARD .EQ.  *
|  |    *    QDEV   *
|  |      *       *
|  |        *   *
|  |          *
|  |          |FALSE
|  |          |
|  |          |
|  |/MAIN 680/|           20
|  |     ----------------
|  |    / WRITE TO DEV  /
|  |   /       6       /
|  |  /   VIA FORMAT  /
|  | /       610     /
|  |/ FROM THE LIST /
|  |----------------
|  |          |
|  |          |
|  |/MAIN 680/|  NOTE  21
|  |* * * * * * * * * * *
|  |*   LIST = QDEV,    *
|  |*       QCARD       *
|  |* * * * * * * * * * *
|  |          |
|  +--------->|
|       110   |  NOTE  22
|     * * * * * * * * * * *
```



AUTOFLOW CHART SET - MCF MODEL PAGE 04

CHART TITLE - PROCEDURES



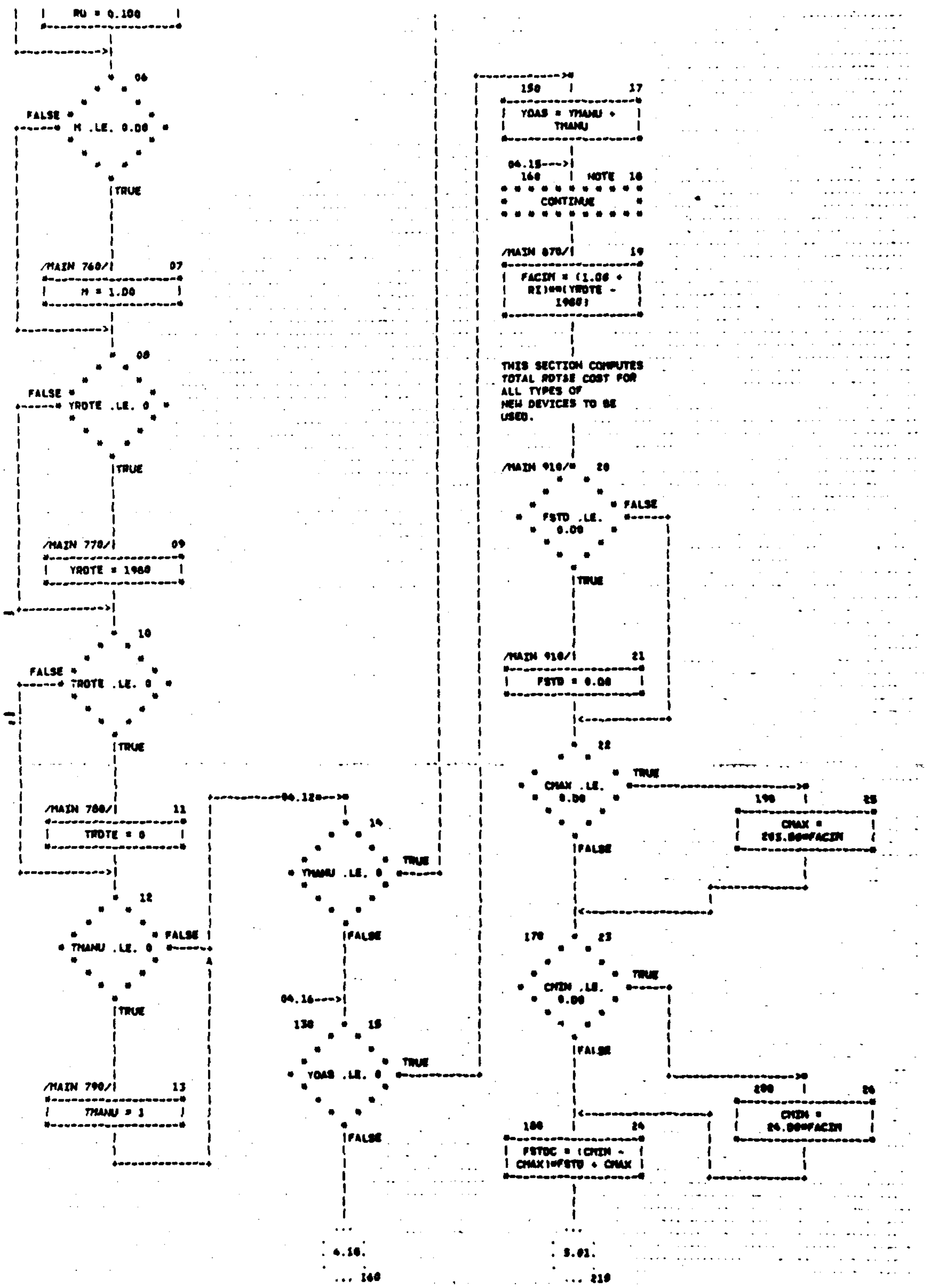

RU = 0.10D
06
FALSE
M .LE. 0.D0
TRUE
/MAIN 760/ 07
M = 1.D0
08
FALSE
YROTE .LE. 0
TRUE
/MAIN 770/ 09
YROTE = 1960
10
FALSE
TROTE .LE. 0
TRUE
/MAIN 780/ 11
TROTE = 0
12
TMANU .LE. 0
FALSE
TRUE
/MAIN 790/ 13
TMANU = 1
04.12
14
YMANU .LE. 0
TRUE
FALSE
04.16
130 15
YOAS .LE. 0
TRUE
FALSE
4.16.
160
150 17
YOAS = YMANU + TMANU
04.15
160 NOTE 18
CONTINUE
/MAIN 870/ 19
FACIN = (1.D0 + RI)**(YROTE - 1960)
THIS SECTION COMPUTES TOTAL ROTSE COST FOR ALL TYPES OF NEW DEVICES TO BE USED.
/MAIN 910/ 20
FSTD .LE. 0.D0
FALSE
TRUE
/MAIN 910/ 21
FSTD = 0.D0
22
CMAX .LE. 0.D0
TRUE
FALSE
190 25
CMAX = 293.D0*FACIN
170 23
CMIN .LE. 0.D0
TRUE
FALSE
200 26
CMIN = 24.D0*FACIN
180 24
FSTDC = (CMIN - CMAX)*FSTD + CMAX
5.01.
210

CHART TITLE - PROCEDURES

```
/ 210 /

04.24--->|  NOTE 01
CONTINUE

/MAIN1010/  02
TRUE  TROTE .EQ. 0
FALSE

/MAIN1020/  NOTE 03
BEGIN DO LOOP
230 I = 1, N

05.07--->|
04
MEM(I) .EQ.  TRUE
0.D0
FALSE

/MAIN1040/  05
|1|  XROTE
|2|  (NG(I),FSTOC,
|.|  ROTEF)
|0|
|1|

220  NOTE 06
CONTINUE

230  07
END OF DO  NO
LOOP?
YES  5
     04

/MAIN1070/  08
IRND
(ROTE0)
```

```
250  15
END OF DO  NO
LOOP?
YES  5
     12

/MAIN1180/  16
IRND
(PURCH0)

THIS SECTION
ESTIMATES THE
PROPORTIONAL
DISTRIBUTION OF MC'S,
QUALITY GRADES
A,B,B1,B2 AND BELOW
ON A CARD.

/MAIN1220/  17
EQA = 0.D0
EQB = 0.D0
EQB1 = 0.D0
EQB2 = 0.D0
EQCD = 0.D0
ERA = 0.D0

/MAIN1280/  NOTE 18
BEGIN DO LOOP
260 I = 1, N

05.23--->|
19
SCRN(I) .LE.  FALSE
0.D0
TRUE

/MAIN1290/  20
SCRN(I) = 2.D0

21
```

```
THIS SECTION COMPUTES
THE SCREENING TEST
COST.

/MAIN1410/  NOTE 26
BEGIN DO LOOP
280 I = 1, N

05.30--->|
27
SCRN(I) .EQ.  TRUE
1.D0
FALSE

/MAIN1430/  28
|1|  XSCR
|0|  (DEVO(I),
|.|  MEM(I),MOS(I),
|0|  NP(I),NG(I),
|4|  RATEE2,RATET4,
     FACIN,MEM(I),
     SCREEN)

270  NOTE 29
CONTINUE

280  30
END OF DO  NO
LOOP?
YES  5
     27

/MAIN1470/  31
IRND
(SCR0)

THIS SECTION COMPUTES
TOTAL CARD ASSEMBLY
COSTS FOR THE
TOTAL QUANTITY OF
CARDS.

/MAIN1510/  32
```

```
/MAIN1580/  NOTE 39
CONTINUED FROM
A PRIOR COLUMN
THE TOTAL QUANTITY OF
CARDS.

/MAIN1590/  40
QCARD = QCARD +
CARD(I)*NMC(I)
QGATE = QGATE +
(NLG(I) +
NDG(I))*CARD(I)
QA(I) =
FQA*NMC(I)

/MAIN1620/  41
IRND
(QA(I))

/MAIN1630/  42
QB(I) =
FQB*NMC(I)

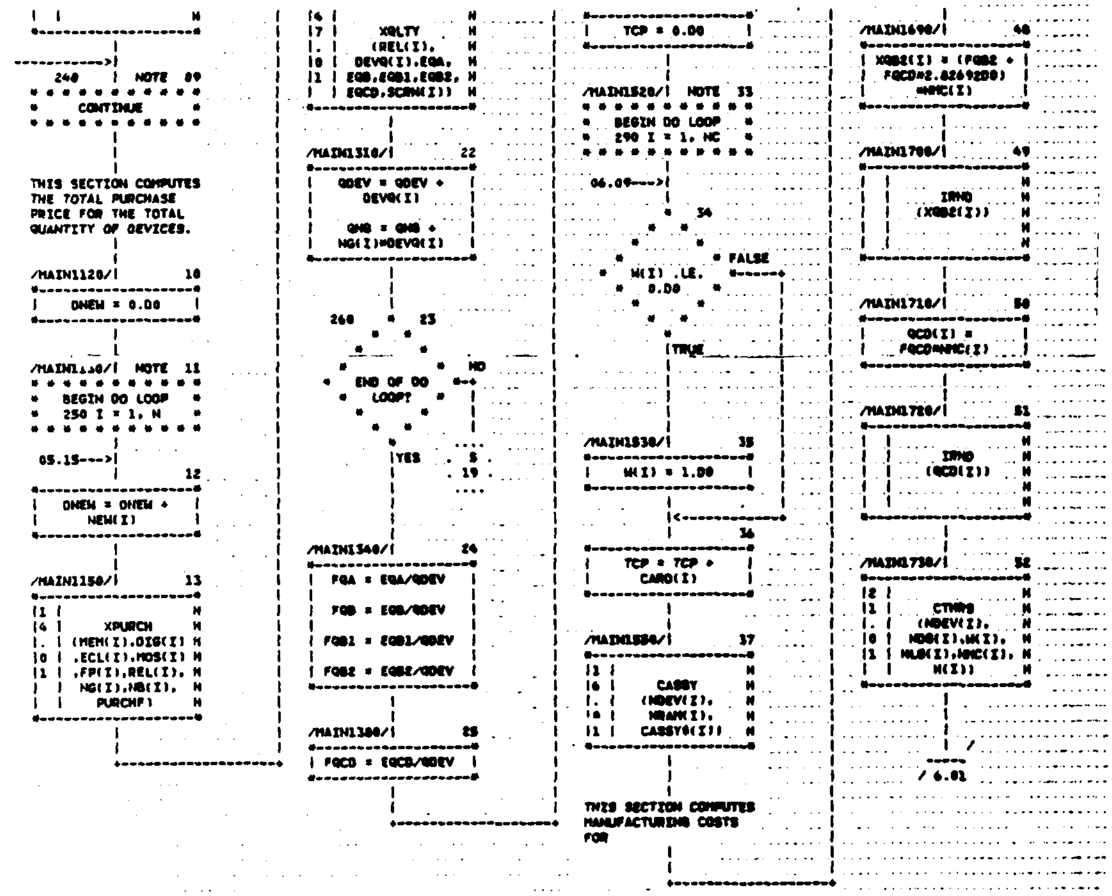
/MAIN1640/  43
IRND
(QB(I))

/MAIN1650/  44
QB1(I) =
FQB1*NMC(I)

/MAIN1660/  45
IRND
(QB1(I))

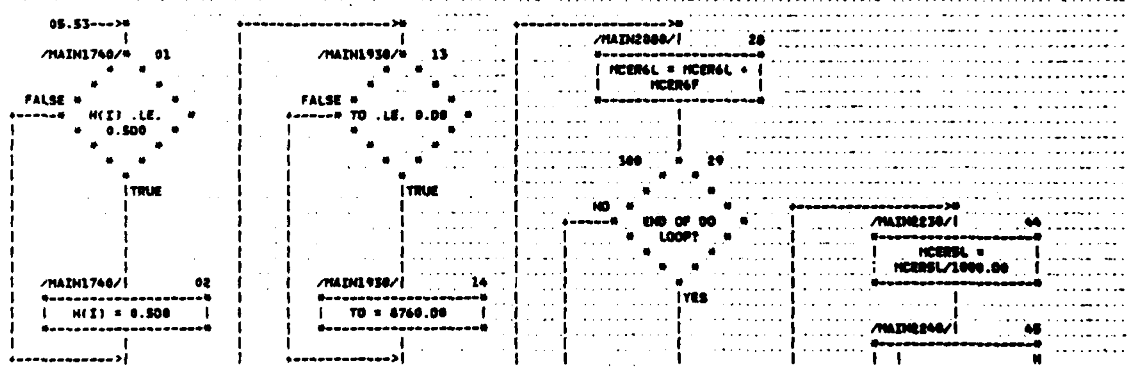
/MAIN1670/  46
QB2(I) =
FQB2*NMC(I)

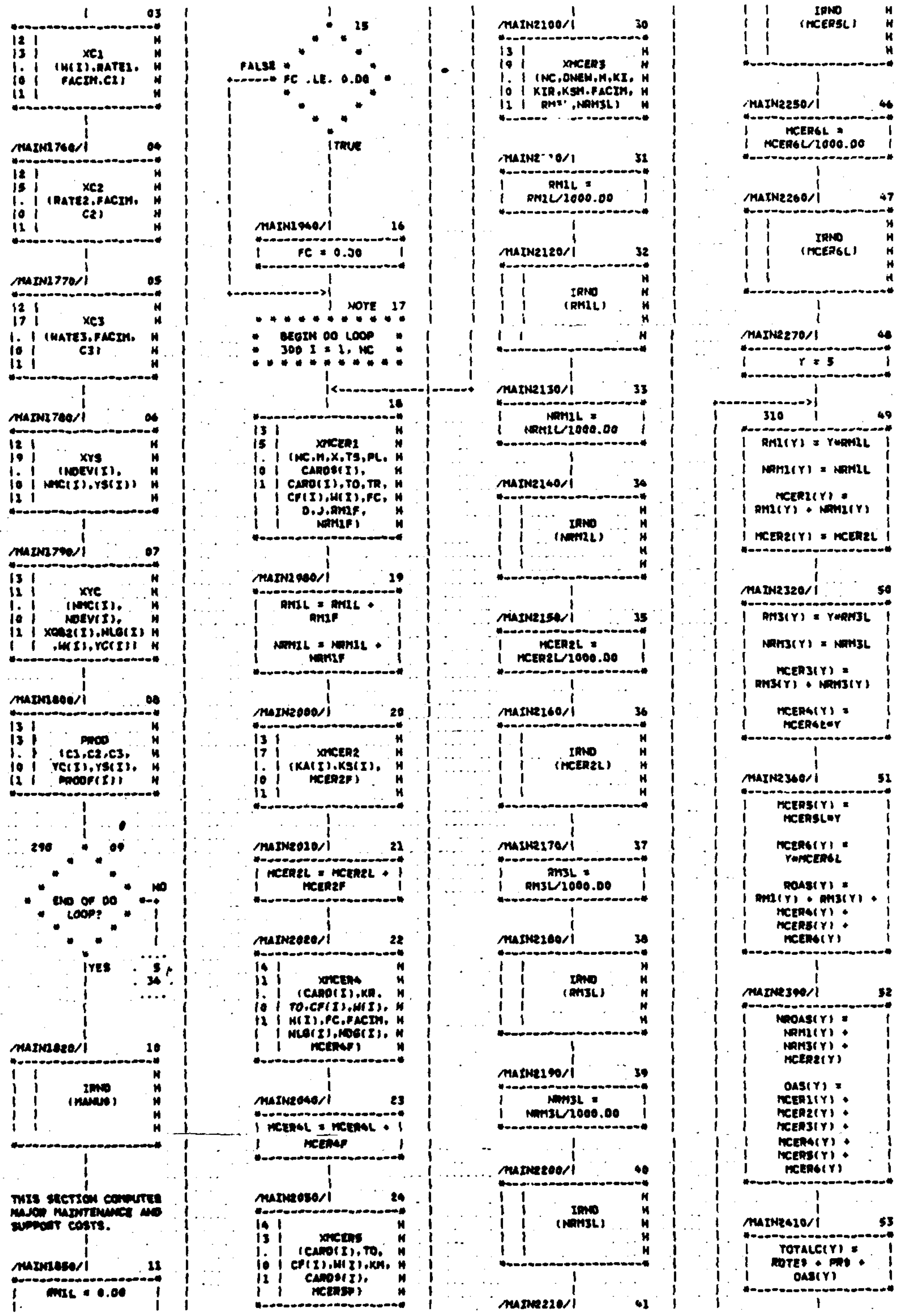
/MAIN1680/  47
IRND
(QB2(I))
```



AUTOFLOW CHART SET - MCF MODEL PAGE 06

CHART TITLE - PROCEDURES





03
XC1 (H(I),RATE1, FACIM,C1)
/MAIN1760/ 04
XC2 (RATE2,FACIM, C2)
/MAIN1770/ 05
XC3 (RATE3,FACIM, C3)
/MAIN1780/ 06
XYS (NDEV(I), NMC(I),YS(I))
/MAIN1790/ 07
XYC (NMC(I), NDEV(I), XOB2(I),HLG(I) ,W(I),YC(I))
/MAIN1800/ 08
PROD (C1,C2,C3, YC(I),YS(I), PRODF(I))
290 09
END OF DO LOOP?
NO
YES
5 34
/MAIN1820/ 10
IRND (MANUG)
THIS SECTION COMPUTES MAJOR MAINTENANCE AND SUPPORT COSTS.
/MAIN1850/ 11
RM1L = 0.00
15
FALSE
FC .LE. 0.00
TRUE
/MAIN1940/ 16
FC = 0.30
NOTE 17
BEGIN DO LOOP 300 I = 1, NC
18
XMCER1 (NC,M,X,TS,PL, CARD9(I), CARD(I),TO,TR, CF(I),W(I),FC, D,J,RM1F, NRM1F)
/MAIN1980/ 19
RM1L = RM1L + RM1F
NRM1L = NRM1L + NRM1F
/MAIN2000/ 20
XMCER2 (KA(I),KS(I), MCER2F)
/MAIN2010/ 21
MCER2L = MCER2L + MCER2F
/MAIN2020/ 22
XMCER4 (CARD(I),KR, TO,CF(I),W(I), H(I),FC,FACIM, HLG(I),HDG(I), MCER4F)
/MAIN2040/ 23
MCER4L = MCER4L + MCER4F
/MAIN2050/ 24
XMCER5 (CARD(I),TO, CF(I),W(I),KM, CARD9(I), MCER5F)
/MAIN2100/ 30
XMCER3 (NC,DNEW,M,KI, KIR,KSM,FACIM, RM3L,NRM3L)
31
RM1L = RM1L/1000.00
/MAIN2120/ 32
IRND (RM1L)
/MAIN2130/ 33
NRM1L = NRM1L/1000.00
/MAIN2140/ 34
IRND (NRM1L)
/MAIN2150/ 35
MCER2L = MCER2L/1000.00
/MAIN2160/ 36
IRND (MCER2L)
/MAIN2170/ 37
RM3L = RM3L/1000.00
/MAIN2180/ 38
IRND (RM3L)
/MAIN2190/ 39
NRM3L = NRM3L/1000.00
/MAIN2200/ 40
IRND (NRM3L)
/MAIN2210/ 41
IRND (MCER5L)
/MAIN2250/ 46
MCER6L = MCER6L/1000.00
/MAIN2260/ 47
IRND (MCER6L)
/MAIN2270/ 48
Y = 5
310 49
RM1(Y) = Y*RM1L
NRM1(Y) = NRM1L
MCER1(Y) = RM1(Y) + NRM1(Y)
MCER2(Y) = MCER2L
/MAIN2320/ 50
RM3(Y) = Y*RM3L
NRM3(Y) = NRM3L
MCER3(Y) = RM3(Y) + NRM3(Y)
MCER4(Y) = MCER4L*Y
/MAIN2360/ 51
MCER5(Y) = MCER5L*Y
MCER6(Y) = Y*MCER6L
ROAS(Y) = RM1(Y) + RM3(Y) + MCER4(Y) + MCER5(Y) + MCER6(Y)
/MAIN2390/ 52
NROAS(Y) = NRM1(Y) + NRM3(Y) + MCER2(Y)
OAS(Y) = MCER1(Y) + MCER2(Y) + MCER3(Y) + MCER4(Y) + MCER5(Y) + MCER6(Y)
/MAIN2410/ 53
TOTALC(Y) = ROTE9 + PR9 + OAS(Y)

```
NRM1L = 0.00
MCER2L = 0.00
RM3L = 0.00
NRM3L = 0.00

/MAIN1900/                12
MCER4L = 0.00
MCER5L = 0.00
MCER6L = 0.00

/MAIN2060/                25
MCER5L = MCER5L +
MCER5F

/MAIN2070/                26
XMCER6
(CARD(I),WC,
TD,KT,FACIM,
CF(I),W(I),FC,
MCER6F)

MCER4L =
MCER4L/1000.00

/MAIN2220/                42
IRND
(MCER4L)

/MAIN2420/                54
Y .GE. 15        TRUE
FALSE    7 . 02 . 320

/MAIN2430/                55
Y = Y + 5
```

AUTOFLOW CHART SET - MCF MODEL PAGE 07

CHART TITLE - PROCEDURES

```
/ 320 /

06.54--->
                NOTE 01
CONTINUE

THIS SECTION
CALCULATES THE LCC
SUMMARY BY FISCAL
YEAR.

/MAIN2480/                02
YROTE = YROTE -
1980
YMANU = YMANU -
1980
YOAS = YOAS -
1980
IYOAS = YOAS + 14

/MAIN2520/      NOTE 03
BEGIN DO LOOP
330 I = YROTE,
IYOAS

                          04
ROTE(I) = 0.00
LINV(I) = 0.00
LOAS(I) = 0.00

330                       05
NO   END OF DO
     LOOP?
YES

----07.13*--->
                          14
LINV(I) =
(PR0)/TMANU

360                       15
NO   END OF DO
<--- LOOP?
YES

/MAIN2670/      NOTE 16
BEGIN DO LOOP
370 I = YOAS,
IYOAS

                          17
LOAS(I) =
ROAS(15)/15.00

370                       18
END OF DO        NO
LOOP?
YES

/MAIN2700/                19
LOAS(YOAS) =
LOAS(YOAS) +
NROAS(15)
```

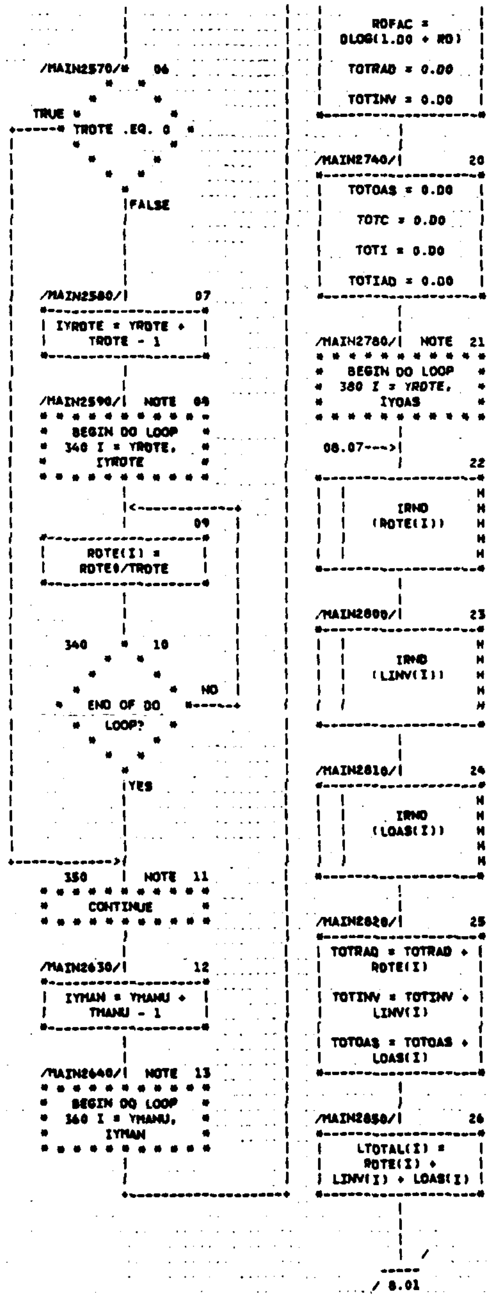

/MAIN2570/ 06
TRUE
TROTE .EQ. 0
FALSE
/MAIN2580/ 07
IYROTE = YROTE + TROTE - 1
/MAIN2590/ NOTE 08
BEGIN DO LOOP 340 I = YROTE, IYROTE
09
ROTE(I) = ROTE0/TROTE
340 10
END OF DO LOOP?
NO
YES
350 NOTE 11
CONTINUE
/MAIN2630/ 12
IYMAN = YMANU + TMANU - 1
/MAIN2640/ NOTE 13
BEGIN DO LOOP 360 I = YMANU, IYMAN
ROFAC = DLOG(1.D0 + RO)
TOTRAD = 0.D0
TOTINV = 0.D0
/MAIN2740/ 20
TOTOAS = 0.D0
TOTC = 0.D0
TOTI = 0.D0
TOTIAD = 0.D0
/MAIN2780/ NOTE 21
BEGIN DO LOOP 380 I = YROTE, IYOAS
08.07--->
22
IRND (ROTE(I))
/MAIN2800/ 23
IRND (LINV(I))
/MAIN2810/ 24
IRND (LOAS(I))
/MAIN2820/ 25
TOTRAD = TOTRAD + ROTE(I)
TOTINV = TOTINV + LINV(I)
TOTOAS = TOTOAS + LOAS(I)
/MAIN2850/ 26
LTOTAL(I) = ROTE(I) + LINV(I) + LOAS(I)
8.01

CHART TITLE - PROCEDURES

```
07.26--->*
/MAIN2860/|          01
*-------------------*
| |                 H
| |      IRND       H
| |  (LTOTAL(I))    H
| |                 H
| |                 H
*-------------------*
          |
          |
/MAIN2870/|          02
*-------------------*
|   TOTC = TOTC +   |
|     LTOTAL(I)     |
|                   |
| LRI(I) = (1.00 +  |
| RI)**(I - YROTE)  |
|                   |
|     LID(I) =      |
| LTOTAL(I)*LRI(I)  |
*-------------------*
          |
          |
/MAIN2900/|          03
*-------------------*
| |                 H
| |      IRND       H
| |    (LID(I))     H
| |                 H
| |                 H
*-------------------*
          |
          |
/MAIN2910/|          04
*-------------------*
|   TOTI = TOTI +   |
|      LID(I)       |
|                   |
|     LRD(I) =      |
| RD/(RDFAC*(1.00 + |
|   RD)**(I + 1))   |
|                   |
|     LIDD(I) =     |
|   LID(I)*LRD(I)   |
*-------------------*
          |
          |
/MAIN2940/|          05
*-------------------*
| |                 H
| |      IRND       H
| |    (LIDD(I))    H
| |                 H
| |                 H
*-------------------*
          |
          |
/MAIN2950/|          06
*-------------------*
| TOTIAD = TOTIAD + |
|      LIDD(I)      |
*-------------------*
          |
          |
   380    *    07
       *     *
     *         *
   *             *    NO
 *   END OF DO     *--+
   *   LOOP?     *    |
     *         *      |
       *     *        |
          *          ....
          |YES      . 7 .
          |         . 22 .
          |          ....
          |
/MAIN2970/|          08
*-------------------*
|   YROTE = YROTE + |
|       1980        |


*------------------>*
|          /MAIN3050/|  NOTE  13
|          * * * * * * * * * * *
|          *   LIST = ROTE$,    *
|          *   ROTE$, ROTE$,    *
|          *   PR$, PR$, PR$,   *
|          *  PURCH$, PURCH$,   *
|          *   PURCH$, SCR$,    *
|          *    SCR$, SCR$,     *
|          *   MANU$, MANU$,    *
|          *  MANU$, OAS(5),    *
|          * OAS(10), OAS(15),  *
|          *     MCER1(5),      *
|          *     MCER1(10),     *
|          *     MCER1(15),     *
|          *     MCER2(5),      *
|          *     MCER2(10),     *
|          *     MCER2(15),     *
|          *     MCER3(5),      *
|          *     MCER3(10),     *
|          * * * * * * * * * * *
|                    |
|                    |
|          /MAIN3080/|  NOTE  14
|          * * * * * * * * * * *
|          *     MCER3(15),     *
|          * MCER4(5), MCER4(1  *
|          *   0),MCER4(15),    *
|          *     MCER5(5),      *
|          *     MCER5(10),     *
|          *     MCER5(15),     *
|          *     MCER6(5),      *
|          *     MCER6(10),     *
|          *     MCER6(15),     *
|          *    TOTALC(5),      *
|          *    TOTALC(10),     *
|          *    TOTALC(15)      *
|          * * * * * * * * * * *
|                    |
|                    |
|          /MAIN3100/|          15
|           -----------------
|          /                 /
|         /  WRITE TO DEV   /
|        /        6        /
```

```
YMANU = YMANU +
1980

YOAS = YOAS +
1980

THIS SECTION PRINTS
THE RESULTS OF THE
LCC STUDY.

/MAIN3020/|          09
/ WRITE TO DEV /
6
/ VIA FORMAT /
510

/MAIN3030/|          10
/ WRITE TO DEV /
6
/ VIA FORMAT /
450

/MAIN3040/|          11
/ WRITE TO DEV /
6
/ VIA FORMAT /
440

/MAIN3050/|          12
/ WRITE TO DEV /
6
/ VIA FORMAT /
460
/ FROM THE LIST /

/ VIA FORMAT /
470

/MAIN3110/|          16
| I = YROTE - 1980 |
| INDEX = YROTE |

390                  17
/ WRITE TO DEV /
6
/ VIA FORMAT /
480
/ FROM THE LIST /

/MAIN3130/|  NOTE  18
*  LIST = INDEX,  *
* ROTE(I), LINV(I), *
*  LOAS(I),  *
*  LTOTAL(I),  *
*  LRI(I), LIO(I),  *
*  LRO(I), LIOO(I)  *

/MAIN3150/*  19
* I .GE. IYOAS *  TRUE
FALSE   8
        21
        400

/MAIN3160/|          20
| I = I + 1 |
| INDEX = INDEX + 1 |

08.19--->*
400                  21
/ WRITE TO DEV /
6
/ VIA FORMAT /
490
/ FROM THE LIST /

/MAIN3190/|  NOTE  22
* LIST = TOTPAO,  *
* TOTINV, TOTOAS,  *
*  TOTC, TOTI,  *
*  TOTIAO  *

3.02
... 80
```

AUTOFLOW CHART SET -   MCF MODEL   PAGE 12

CHART TITLE - SUBROUTINE XROTE(NG,FSTDC,ROTEF)

```
/ XROTE /

05.05--->*

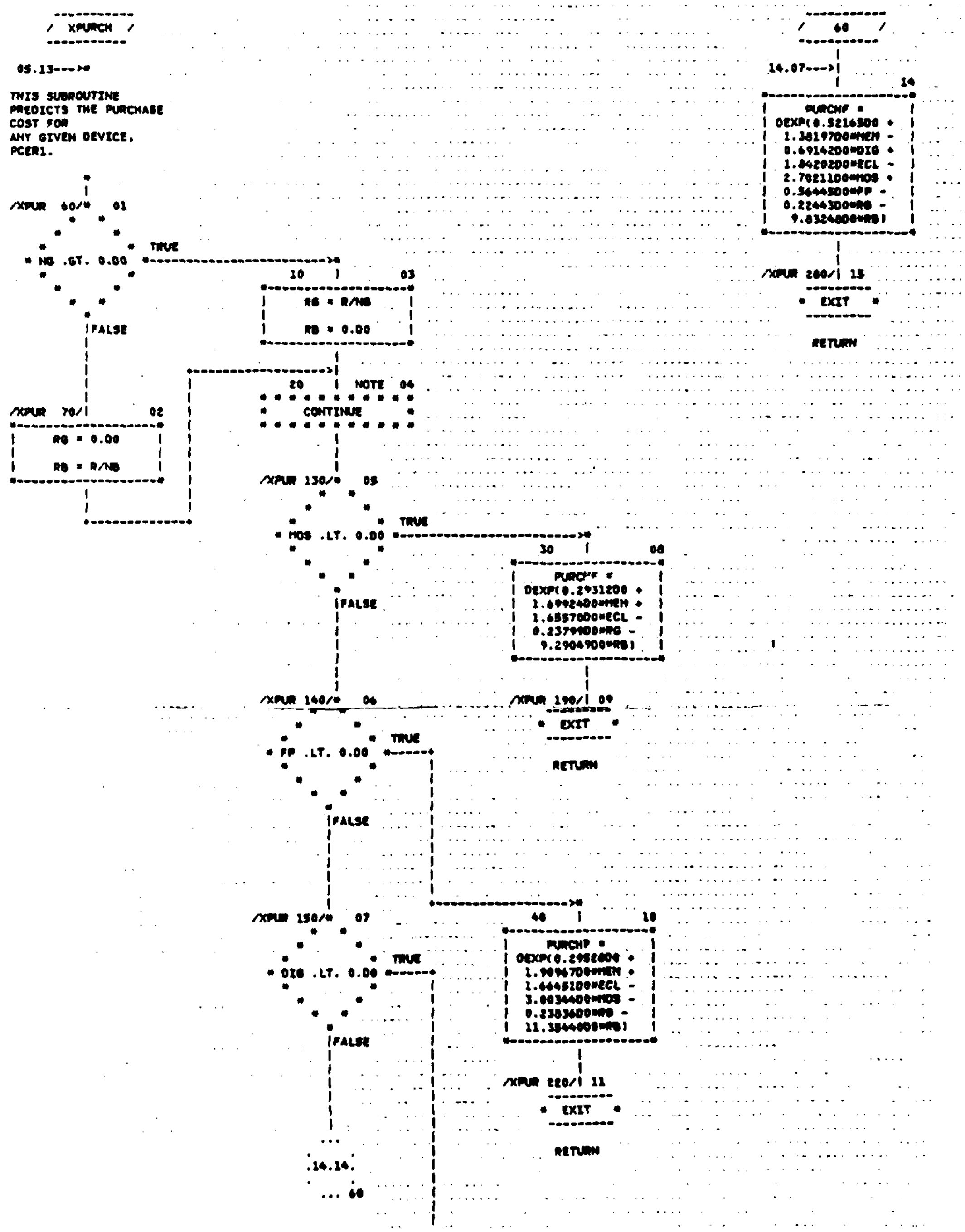
THIS SUBROUTINE
PREDICTS THE COST OF
RDT&E FOR
NEW DEVICES, RCER.

/XROT 100/|          01
| ROTEF = NG*FSTDC |

/XROT 110/| 02
* EXIT *

RETURN
```

CHART TITLE - SUBROUTINE XPURCH(MEM,DIG,ECL,MOS,FP,R,NG,NB,PURCHF)



```
            |
            |
            *-------------------->*
                          50      |          12
                    *--------------------*
                    |      PURCHF =      |
                    | DEXP(0.02207D0 +   |
                    |  1.8446lD0*MEM +   |
                    |  1.58816D0*ECL -   |
                    |  2.66517D0*MOS +   |
                    |  0.60918D0*FP -    |
                    |  0.20841D0*RG -    |
                    |   9.15497D0*RB)    |
                    *--------------------*
                              |
                    /XPUR 250/| 13
                       ---- ----
                       *  EXIT   *
                       ---------
```


CHART TITLE - SUBROUTINE CASSY(NDEV,NRAM,CASSY$)

```
            -----------
           /  CASSY   /
           -----------

        05.37--->*

        THIS SUBROUTINE
        COMPUTES CARD
        ASSEMBLY COST, PCER3.

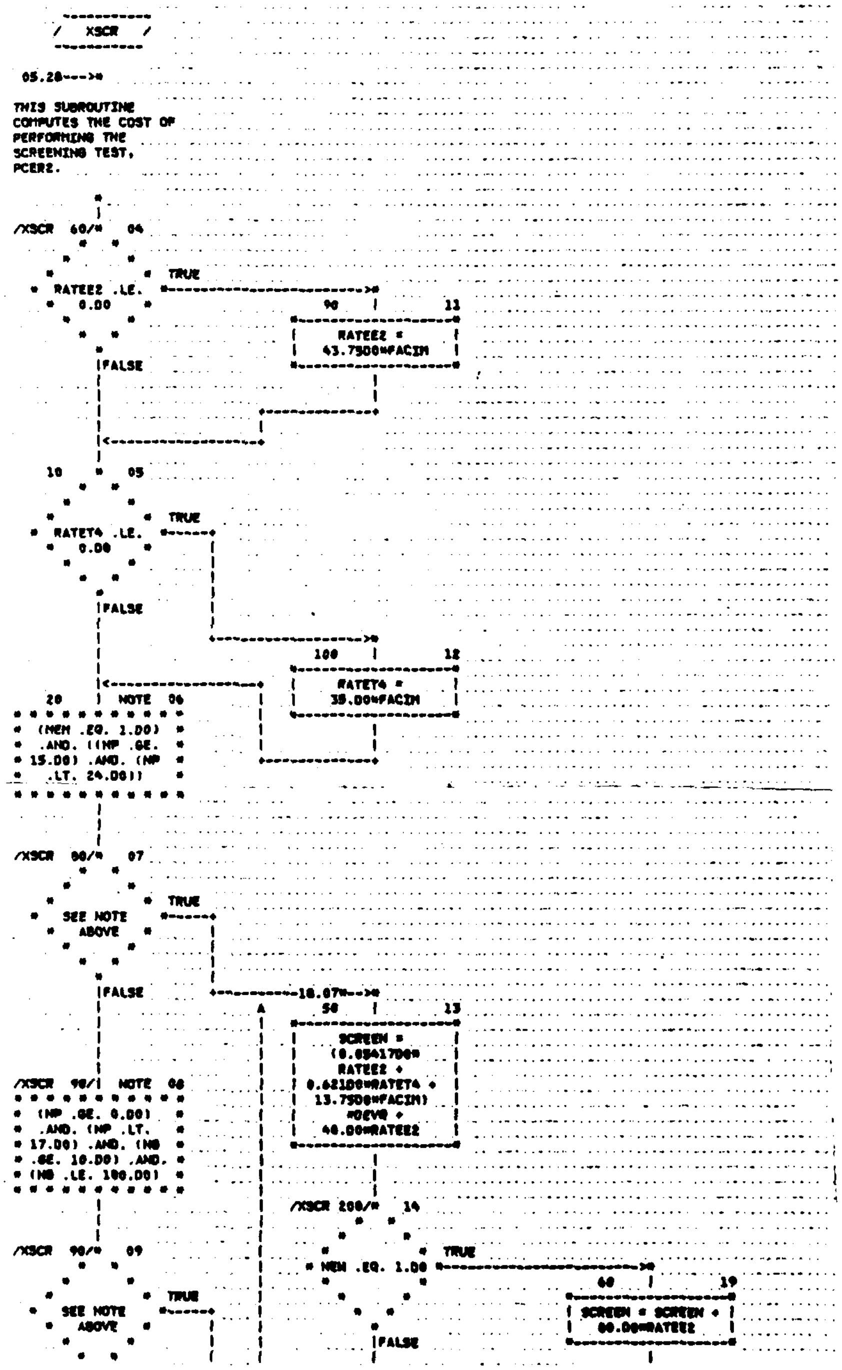
                *
                |
        /CASS  40/*    01
                *   *
              *       *
            *           *  TRUE
          *   NRAM .LT.   *-+
            *   0.D0    *   |
              *       *     |
                *   *       |
                  *       ....
                  |FALSE  .  .
                  |       ....
                  |        10
                  |
        /CASS  50/| 02
             ---------
             * EXIT  *
             ---------

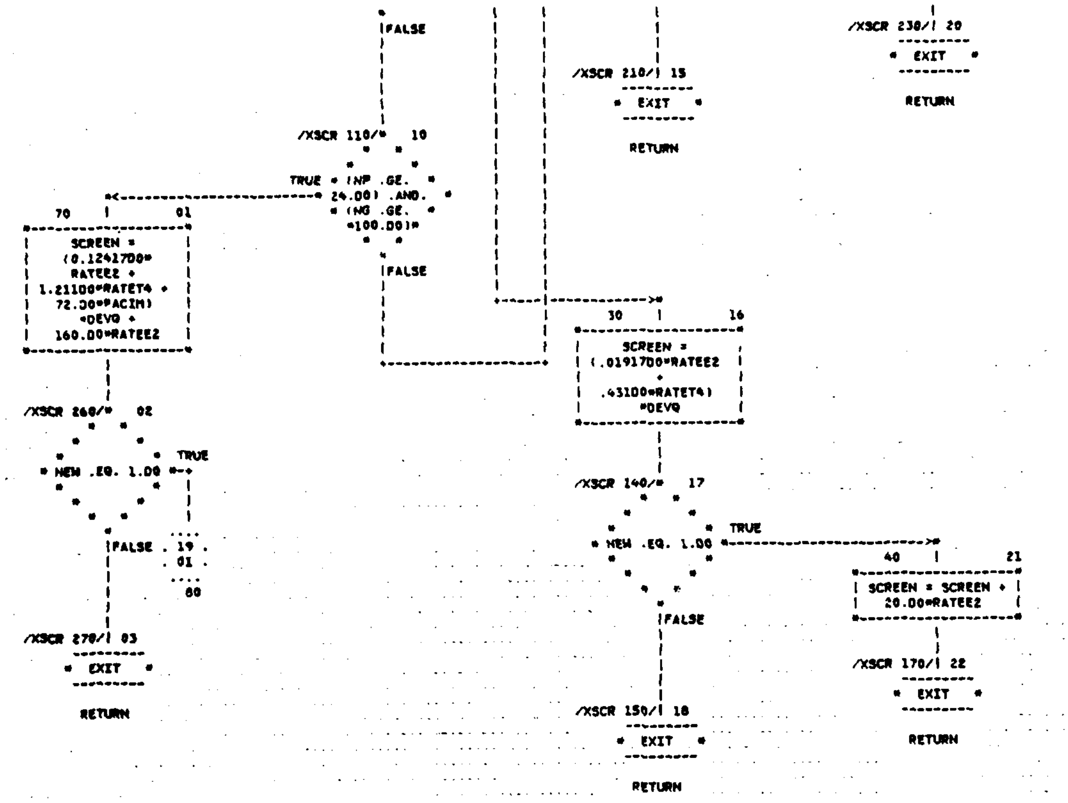
              RETURN


            -----------
           //CASS  60//
           -----------
                |
                | 03
             ---------
             * EXIT  *
             ---------

              RETURN
```

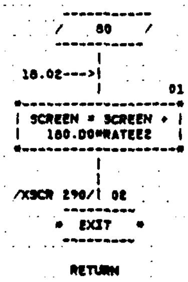
CHART TITLE - SUBROUTINE XSCR(DEVQ,MEM,MOS,NP,NB,RATEE2,RATET4,FACIM,NEW,SCREEN





AUTOFLOW CHART SET - HCF MODEL PAGE 19

CHART TITLE - SUBROUTINE XSCR(DEVQ,MEM,MOS,NP,NG,RATEE2,RATET4,FACIM,NEW,SCREEN



```
                                    AUTOFLOW CHART SET -        MCF MODEL                PAGE  21

CHART TITLE - SUBROUTINE  CTHRS(NDEV,NDG,W,NLS,NMC,H)


               -----------
              /  CTHRS   /
              -----------

           05.52--->*

           THIS SUBROUTINE
           IMPLEMENTS THE CARD
           TEST HOURS CER, H.

                     *
                     |
           /CTHR  40/*    01
                  *     *
                *         *
              *             *  TRUE
            * NLS  .LT.  0.D0 *------------------------>*
              *             *                10    |         04
                *         *                 *---------------------*
                  *     *                   | H = 0.3701600 +     |
                     *                      |   0.0000089100*     |
                     |FALSE                 |   NDEV*NDG +        |
                     |                      | 5.1376600*(1.D0 -   |
                     |                      |   W)                |
                     |                      *---------------------*
                     |                                 |
                     |                                 |
           /CTHR  50/|            02        /CTHR  90/| 05
           *--------------------*                ---------
           | H = - 0.2966900 +  |                * EXIT  *
           |  0.0000088900*     |                ---------
           |   NDEV*NDG +       |
           | 4.9990600*(1.D0 -  |                 RETURN
           |    W) +            |
           |  0.0151400*NLS +   |
           |  1.9830700*(NMC/   |
           |    NDEV)**2        |
           *--------------------*
                     |
                     |
           /CTHR  70/| 03
                 ---------
                 * EXIT  *
                 ---------

                  RETURN


                                    AUTOFLOW CHART SET -        MCF MODEL                PAGE  23

CHART TITLE - SUBROUTINE  XC1(H,RATE1,FACIM,C1)


               -----------
              /   XC1    /
              -----------

           06.03--->*

           THIS SUBROUTINE
           COMPUTES C1, WHICH IS
           USED IN
           LATER CALCULATIONS.

                     *
                     |
           /XC1   50/*    01
                  *     *
                *         *
              *             *  TRUE
            *  RATE1  .LE.   *------------------------>*
              *   0.D0      *               20    |         04
                *         *                 *---------------------*
                  *     *                   |   RATE1 =           |
                     *                      |  26.900*FACIM       |
                     |FALSE                 *---------------------*
                     |                                |
                     |                                |
                     |                   *------------*
                     |                   |
                     |<------------------*
             10      |          02
           *--------------------*
           |  C1 = RATE1**H     |
           *--------------------*
```

```
             |
/XC1   70/| 03
        ---------
        * EXIT   *
        ---------

        RETURN
```

AUTOFLOW CHART SET -   MCF MODEL   PAGE 25

CHART TITLE - SUBROUTINE XC2(RATE2,FACIM,C2)

```
        -----------
       /   XC2    /
       -----------

  06.04--->*

  THIS SUBROUTINE
  COMPUTES C2, WHICH IS
  USED IN
  LATER CALCULATIONS.

           *
           |
/XC2   50/*    01
         *   *
       *       *
     *           *  TRUE
   *  RATE2 .LE.   *------------------------->*
     *  0.00     *              20     |          04
       *       *             *--------------------*
         *   *               |      RATE2 =       |
           *                 |   26.900*FACIM     |
           |FALSE            *--------------------*
           |                           |
           |                           |
           |                 *---------*
           |                 |
           |<----------------*
      10   |            02
*---------------------*
| C2 = RATE2*0.500    |
*---------------------*
           |
/XC2   70/| 03
       ---------
       * EXIT   *
       ---------

       RETURN
```

AUTOFLOW CHART SET -   MCF MODEL   PAGE 27

CHART TITLE - SUBROUTINE XC3(RATE3,FACIM,C3)

```
        -----------
       /   XC3    /
       -----------

  06.05--->*

  THIS SUBROUTINE
  COMPUTES C3, WHICH IS
  USED IN LATER
  CALCULATIONS.

           *
           |
/XC3   50/*    01
         *   *
       *       *
     *           *  TRUE
   *  RATE3 .LE.   *------------------------->*
     *  0.00     *              20     |          04
       *       *             *--------------------*
         *   *               |      RATE3 =       |
           *                 |   28.300*FACIM     |
           |FALSE            *--------------------*
           |                           |
```

```
          |
          |                     +---------------+
          |                     |
          |<--------------------+
    10    |          02
#--------------------#
| C3 = RATE3*0.2600  |
#--------------------#
          |
          |
/XC3   70/| 03
      ---------
      *  EXIT   *
      ---------

       RETURN
```

```
                    AUTOFLOW CHART SET -          MCF MODEL                         PAGE  29

CHART TITLE - SUBROUTINE  XYS(NDEV,NMC,YS)
```

```
             -----------
            /   XYS     /
            -----------

          06.06--->*

          THIS SUBROUTINE
          COMPUTES THE SYSTEMS
          TEST YIELD, YS.

                    *
          /XYS   40/|          01
          #---------------------#
          |        YS =         |
          | DEXP(-0.00094D0*    |
          |       NDEV -        |
          |   0.00100*NMC)      |
          #---------------------#
                    |
                    |
          /XYS   50/| 02
              ---------
              *  EXIT   *
              ---------

               RETURN
```

```
                    AUTOFLOW CHART SET -          MCF MODEL                         PAGE  31

CHART TITLE - SUBROUTINE  XYC(NMC,NDEV,QB2,NLG,M,YC)
```

```
         -----------
        /   XYC     /
        -----------

  06.07--->*

  THIS SUBROUTINE
  IMPLEMENTS THE TEST
  FRACTIONAL YIELD CER,
  YC.

          *
          |
  /XYC   40/*    01
          *   *
        *       *
      *           *  TRUE
    * NLG .LT. 0.D0 *---------------------------->*
      *           *                    10   |          04
        *       *                     #---------------------#
          *   *                       |        YC =         |
            *                         | 10**(-0.31298D0*    |
            |FALSE                    |    (NMC/NDEV))      |
            |                         #---------------------#
            |                                   |
            |                                   |
            |                         /XYC   90/| 05
            |                             ---------
  /XYC   50/|          02                 *  EXIT   *
  #---------------------#                 ---------
  |        YC =         |
  | 10**(-0.20504D0*    |                  RETURN
  |    (NMC/NDEV) -     |
```

```
|   0.0014600*QB2 -   |
|   0.0012200*NLG -   |
|  0.1484200*(1.00 -  |
|         W))         |
*---------------------*
           |
           |
/XYC   70/| 03
       ---------
       *  EXIT   *
       ---------

        RETURN
```

AUTOFLOW CHART SET -   MCF MODEL   PAGE 33

CHART TITLE - SUBROUTINE PROD(C1,C2,C3,YC,YS,PROOF)

```
          -----------
         /   PROD   /
        -----------

     06.08--->*

     THIS SUBROUTINE
     PREDICTS THE
     MANUFACTURING COSTS
     FOR ANY CARD TYPE,
     PCER4.

                *
     /PROD  50/|          01
     *--------------------*
     |   PROOF = (C1 +    |
     |      C2*YC +       |
     |    C3*(1.00 -      |
     |  YC*YS))/(YC*YS)   |
     *--------------------*
                |
                |
     /PROD  60/| 02
           ---------
           *  EXIT   *
           ---------

            RETURN
```

AUTOFLOW CHART SET -   MCF MODEL   PAGE 35

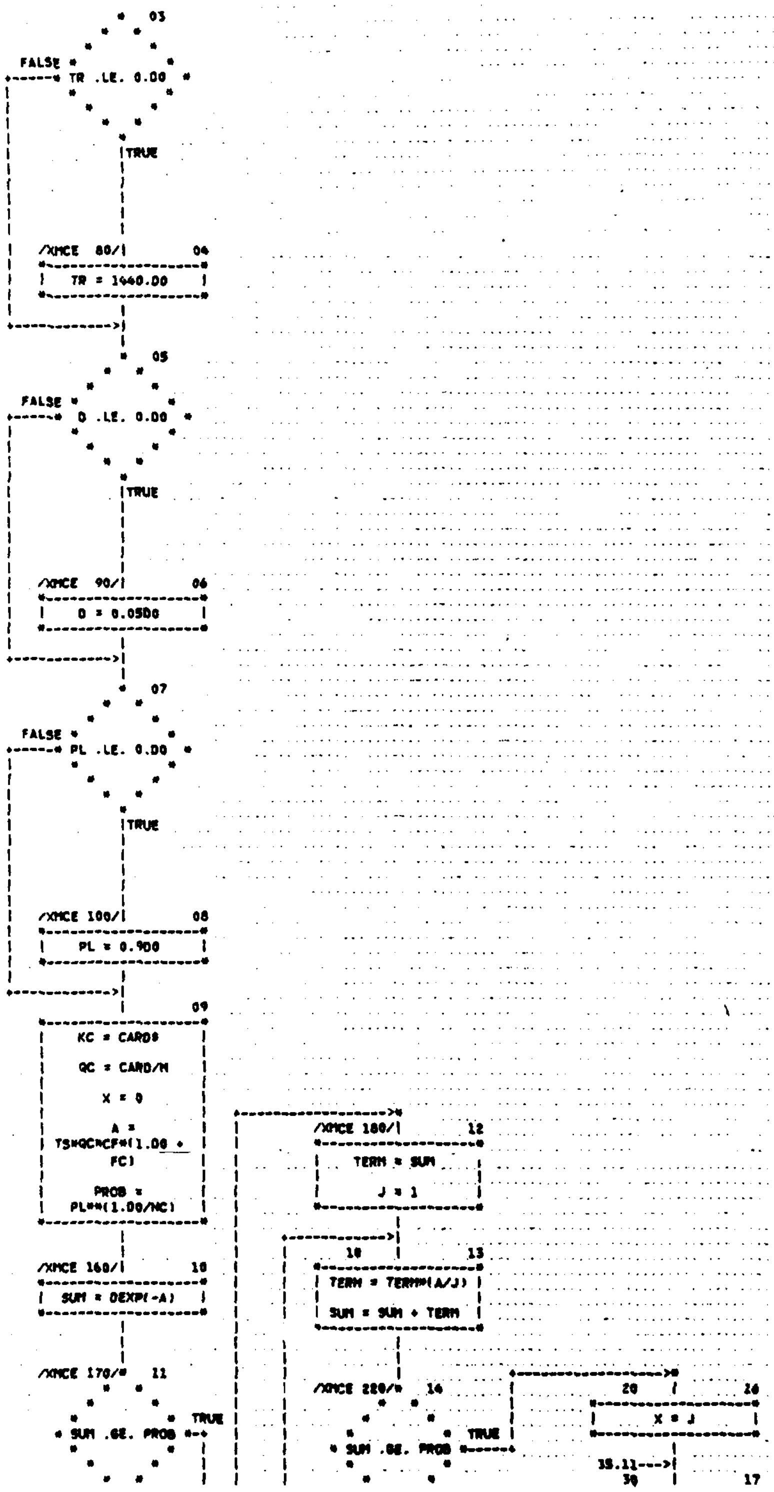
CHART TITLE - SUBROUTINE XMCER1(NC,M,X,TS,PL,CARD9,CARO,TO,TR,CF,W,FC,D,J,RM2F,

```
            -----------
           /  XMCER1  /
          -----------

        06.18--->*

        THIS SUBROUTINE
        COMPUTES THE INITIAL
        STOCK AND PIPELINE
        PLUS REPLENISHMENT
        CER, MCER1.

                  *
                  |
        /XMCE  70/*   01
                *   *
              *       *
      FALSE *           *
   *------* TS .LE. 0.00  *
   |        *           *
   |          *       *
   |            *   *
   |              *
   |              |TRUE
   |              |
   |              |
   |              |
   |              |
   |    /XMCE  70/|         02
   |    *-------------------*
   |    |    TS = 336.00    |
   |    *-------------------*
   |              |
   *------------->|
                  |
```


03
FALSE
TR .LE. 0.00
TRUE
/XMCE 80/ 04
TR = 1440.00
05
FALSE
D .LE. 0.00
TRUE
/XMCE 90/ 06
D = 0.0500
07
FALSE
PL .LE. 0.00
TRUE
/XMCE 100/ 08
PL = 0.900
09
KC = CARD$
QC = CARD/M
X = 0
A = TS*QC*CF*(1.00 + FC)
PROB = PL**(1.00/MC)
/XMCE 160/ 10
SUM = DEXP(-A)
/XMCE 170/ 11
SUM .GE. PROB
TRUE
/XMCE 180/ 12
TERM = SUM
J = 1
18
13
TERM = TERM*(A/J)
SUM = SUM + TERM
/XMCE 220/ 14
SUM .GE. PROB
TRUE
20
16
X = J
15.11--->
30
17

```
*        ....  |    |           *   *              *-----------------------*
|FALSE . 35 .  |    |            *                 |        MULT =         |
|       . 17 . |    |            |FALSE            |  TO*QC*CF*(1.D0 +     |
|        ....  |    |            |                 |          FC)          |
|         30   |    |            |                 |                       |
|              |    |            |                 |        RM1F =         |
|              |    |            |                 |    W*D*MULT*KC*M      |
*--------------*    |            |                 |                       |
                    |  /XMCE 230/|          15     | NRM1F = M*KC*(X +     |
                    |  *----------------------*    |   (TR/8760.D0)        |
                    |  |      J = J + 1       |    |        *MULT)         |
                    |  *----------------------*    *-----------------------*
                    |            |                             |
                    |            |                             |
                    *------------*                 /XMCE 290/| 18
                                                        ---------
                                                        *  EXIT  *
                                                        ---------

                                                          RETURN
```


CHART TITLE - SUBROUTINE XMCER2(KA,KS,MCER2F)

```
                  ----------
                 / XMCER2 /
                 ----------

              06.20--->*

             THIS SUBROUTINE
             COMPUTES THE SUPPORT
             EQUIPTMENT CER,
             MCER2.

                       *
                       |
             /XMCE  40/*   01
                     *   *
                   *       *
           FALSE *           *
          *-----* KA .LE. 0.D0 *
          |        *         *
          |          *     *
          |            *
          |            |TRUE
          |            |
          |            |
          |            |
          |  /XMCE  40/|         02
          |  *---------------------*
          |  |     KA = 0.D0       |
          |  *---------------------*
          |            |
          *----------->|
                       |
                       *   03
                     *   *
                   *       *
           FALSE *           *
          *-----* KS .LE. 0.D0 *
          |        *         *
          |          *     *
          |            *
          |            |TRUE
          |            |
          |            |
          |            |
          |  /XMCE  50/|         04
          |  *---------------------*
          |  |     KS = 0.D0       |
          |  *---------------------*
          |            |
          *----------->|
                       |         05
             *---------------------*
             | MCER2F = KA + KS    |
             *---------------------*
                       |
             /XMCE  70/| 06
                   ---------
                   *  EXIT  *
                   ---------

                    RETURN
```

CHART TITLE - SUBROUTINE XMCER3(NC,ONEW,M,KI,KIR,KSM,FACIM,RM3L,NRM3L)

```
             / XMCER3 /

     06.30--->*

   THIS SUBROUTINE
   COMPUTES THE
   INVENTORY ENTRY
   OF SUPPLY MANAGEMENT
   CER, MCER3.

   /XMCE 60/*   01
        *  TRUE
   * KI .LT. 0.D0 *-------------------->*
                              40   |    10
                      | KI = 54.D0*FACIM |
              |FALSE
              |<------------------
   10   *   02
        *  TRUE
   * KIR .LT. 0.D0 *----
              |FALSE
                              50   |    11
                      |     KIR =          |
              |<---   |  128.D0*FACIM      |
   20   *   03
        *  TRUE
   * KSM .LT. 0.D0 *----
              |FALSE
              |<--------
   30   *   04
                              60   |    12
 FALSE *                | KSM = 42.D0*FACIM |
 ------* KI .EQ. 0.D0 *
              |TRUE

   /XMCE 90/|        05
   |  KIR = 0.D0  |
   ------------>|
                *   06
```

```
               *         *
   FALSE *                 *
 +------* KIR .EQ. 0.D0 *
 |           *           *
 |             *       *
 |               *   *
 |                 *
 |                 |TRUE
 |                 |
 |                 |
 |                 |
 |     /XMCE 100/|            07
 |     *---------------------*
 |     |      KI = 0.D0      |
 |     *---------------------*
 |                 |
 +---------------->|
                   |          08
       *---------------------*
       |  RMSL = ((DNEW +    |
       |   NC + 1)*KIR +     |
       |     M*NC*KSM)       |
       |                     |
       |  NRMSL = (DNEW +    |
       |   NC + 1)*KI        |
       *---------------------*
                   |
                   |
       /XMCE 130/| 09
             ----------
             *  EXIT  *
             ----------

              RETURN
```

AUTOFLOW CHART SET - MCF MODEL PAGE 41

CHART TITLE - SUBROUTINE XMCER4(CARD,KR,TQ,CF,W,M,FC,FACIM,NLG,NOG,MCER4F)

```
            ------------
            /  XMCER4  /
            ------------

      06.22--->*

      THIS SUBROUTINE
      COMPUTES THE REPAIR
      LABOR CER, MCER4.

                *
                |
      /XMCE  40/*   02
              *   *
            *       *
          *           *  TRUE
        * KR  .LE. 0.D0  *-------------------------->*
          *           *                    20   |        07
            *       *                    *------------------*
              *   *                      | KR = 20.D0*FACIM |
                *                        *------------------*
                |FALSE                          |
                |                               |
                |                  *------------*
                |                  |
                |                  |
      /XMCE  50/|          02      |
      *-------------------*        |
      |     LF = 1.5D0    |        |
      *-------------------*        |
                |                  |
                |                  |
                |                  |
      /XMCE  60/*   03             |
              *   *                |
            *       *              |
   FALSE *           *             |
 +------* NLG .GT. NOG  *          |
 |        *           *            |
 |          *       *              |
 |            *   *                |
 |              *                  |
 |              |TRUE              |
 |              |                  |
 |              |                  |
 |              |                  |
 |    /XMCE  60/|          04      |
 |    *-------------------*        |
```

```
|   |       LF = 3.00       |          |
|   *-----------------------*          |
|               |                      |
*------------->|<---------------------*
       10      |             05
   *-----------------------*
   |       MCER4F =        |
   | KR*TO*CARD*W*CF*      |
   |   (0.2600 + H +       |
   |       LF*FC)          |
   *-----------------------*
               |
               |
   /XMCE  80/| 06
          ---------
        *  EXIT   *
          ---------

          RETURN
```

AUTOFLOW CHART SET - MCF MODEL PAGE 43

CHART TITLE - SUBROUTINE XMCERS(CARD,TO,CF,W,KM,CARD$,MCERSF)

```
        -----------
       /  XMCERS  /
       -----------

   06.24--->*

  THIS SUBROUTINE
  COMPUTES THE REPAIR
  MATERIALS
  COST CER, MCERS.

              *
              |
  /XMCE  60/*    01
            *   *
          *       *
        *           *  TRUE
      * KM  .LE. 0.00  *------------------------->*
        *           *                    20       |       04
          *       *                      *-----------------------*
            *   *                        | KM = 0.?500*CARD$     |
              *                          *-----------------------*
              |FALSE                              |
              |                                   |
              |                      *-------------*
              |                      |
              |                      |
              |<---------------------*
       10     |            02
  *-----------------------*
  |       MCERSF =        |
  |  TO*CARD*W*CF*KM      |
  *-----------------------*
              |
              |
  /XMCE  80/| 03
          ---------
        *  EXIT   *
          ---------

          RETURN
```

AUTOFLOW CHART SET - MCF MODEL PAGE 45

CHART TITLE - SUBROUTINE XMCER6(CARD,WC,TO,KT,FACIN,CF,W,FC,MCER6F)

```
        -----------
       /  XMCER6  /
       -----------

   06.26--->*

  THIS SUBROUTINE
  COMPUTES THE
  MAINTENANCE
  TRANSPORTATION COST
  CER, MCER6.

              *
              |
  /XMCE  60/*    01
            *   *
```

```
                 *         *
      FALSE *                 *
     *------* WC .LE. 0.00    *
     |        *               *
     |          *          *
     |             *    *
     |               *
     |               |TRUE
     |               |
     |               |
     |               |
     |               |
     |  /XMCE  60/|              02
     |  *---------------------*
     |  |     WC = 1.00       |
     |  *---------------------*
     |               |
     *------------->|
                     |
                     *  03
                  *     *
               *           *
            *                 *  TRUE
          * KT .LE. 0.00      *---------------------->*
            *                 *               20      |        06
               *           *               *---------------------*
                  *     *                  | KT = 0.5D0*FACIM    |
                     *                     *---------------------*
                     |FALSE                           |
                     |                                |
                     |                    *-----------*
                     |                    |
                     |                    |
                     |<-------------------*
         10          |          04
     *---------------------*
     |      MCER6F =       |
     | 2.D0*WC*TO*CARD*    |
     |    CF*W*(1.D0 +     |
     |       FC)*KT        |
     *---------------------*
                     |
                     |
     /XMCE   90/| 05
              ---------
            *   EXIT   *
              ---------

              RETURN
```


CHART TITLE - SUBROUTINE XQLTY(REL,DEVQ,EQA,EQB,EQB1,EQB2,EQCD,SCRN)

```
          -----------
          /  XQLTY   /
          -----------

     05.21--->*

     THIS SUBROUTINE
     ESTIMATES THE
     QUANTITIES OF MC'S.
     QUALITY GRADES
     A,B,B1,B2,AND BELOW
     FROM
     THE DEVICE
     RELIABILITIES.

                 *
                 |
     /XQLT  60/*    01
               *     *
            *           *
         *                 *  TRUE
       *    REL .EQ.       *----------------------->*
         *    0.5D0      *               10         |          08
            *           *               *---------------------*
               *     *                  | EQA = EQA + DEVQ    |
                 *                      *---------------------*
                 |FALSE                             |
                 |                                  |
                 |                      /XQLT 140/| 09
                 |                           ---------
                 |                         *   EXIT   *
                 |                           ---------
     /XQLT  70/*    02
               *     *                        RETURN
```

```
           *     *
        *           *  TRUE
      * REL .EQ. 1.D0 *------+
        *           *        |
           *     *           |
              * *            |
               *             |
               |FALSE        |
               |             +------------------->*
               |                         20    |          10
               |                         *--------------------*
               |                         | EQB = EQB + DEVQ   |
               |                         *--------------------*
/XQLT  60/|  NOTE  03                           |
* * * * * * * * * * * *                         |
* (REL .EQ. 3.0D0)    *                /XQLT 160/| 11
*   .OR. ((REL .GE.   *                     ---------
*    6.5D0) .AND.     *                     * EXIT  *
* (SCRN .EQ. 2.D0))   *                     ---------
* * * * * * * * * * * *
               |                             RETURN
               |
               |
/XQLT  80/*    04
           *     *
        *           *  TRUE
      *   SEE NOTE    *------+
        *   ABOVE   *        |
           *     *           |
              * *            +------------------->*
               *                         30    |          12
               |FALSE                    *--------------------*
               |                         |   EQB1 = EQB1 +    |
               |                         |       DEVQ         |
               |                         *--------------------*
               |                                |
               |                                |
               |                       /XQLT 180/| 13
/XQLT 100/*    05                           ---------
           *     *                          * EXIT  *
        *           *  TRUE                 ---------
      *   REL .EQ.    *------+
        *   6.5D0   *        |               RETURN
           *     *           |
              * *            |
               *             |
               |FALSE        |
               |             |
               |             |
               |             +------------------->*
/XQLT 110/|               06             40    |          14
*--------------------*                   *--------------------*
|   EQCD = EQCD +    |                   |   EQB2 = EQB2 +    |
|       DEVQ         |                   |       DEVQ         |
*--------------------*                   *--------------------*
          |                                     |
          |                                     |
/XQLT 120/| 07                         /XQLT 200/| 15
      ---------                             ---------
      * EXIT  *                             * EXIT  *
      ---------                             ---------

       RETURN                                RETURN
```

CHART TITLE - FUNCTION IRND(A)

```
              THIS FUNCTION ROUNDS
              THE LCC ESTIMATES TO
              THE NEAREST INTEGER.

                        *
              /IRND  40/|          01
              *--------------------*
              |      IRND = A      |
              |                    |
              | B = DFLOAT(IRND)   |
              *--------------------*
                        |
                        |
                        |
              /IRND  60/*   02
                       *  *
                     *      *
            FALSE *           *
           *-----*  A - B .GE.  *
           |       *   0.500   *
           |         *       *
           |           *  *
           |            *
           |            |TRUE
           |            |
           |            |
           |            |
           |            |
           |  /IRND  60/|          03
           |  *--------------------*
           |  |  IRND = IRND + 1   |
           |  *--------------------*
           |            |
           *----------->|
                        |          04
              *--------------------*
              | A = DFLOAT(IRND)   |
              *--------------------*
                        |
                        |
              /IRND  80/| 05
                    ---------
                   *  EXIT   *
                    ---------
```

B.2 LCC MODEL SOURCE LISTING

```
C     MCF COMPUTERIZED MODEL
C
      IMPLICIT REAL*8(A-H,K-Z)
      INTEGER X,Y,NC,N,YRDTE,TRDTE,YMANU,TMANU,YOAS
      DIMENSION NEW(100), SCRN(100), MEM(100), DIG(100), ECL(100), CF(10
     10), MOS(100), FP(100), NG(100), NB(100), DEVQ(100), REL(100), CARD
     2(100), NDEV(100), NMC(100), QA(100), QB(100), QB1(100), QB2(100),
     3NDG(100), NLG(100), NRAM(100), W(100), KA(100), KS(100), NP(100),
     4H(100), YS(100), YC(100), XQB2(100), CASSYS(100), MCER1(100), MCER
     52(100), MCER3(100), QCD(100), PRODF(100), CARDS(100), MCER4(100),
     6MCER5(100), MCER6(100), OAS(100), RDTE(100), PURCH(100), SCR(100),
     7 MANU(100), LOAS(100), TOTALC(100), LINV(100), LTOTAL(100), LRI(10
     80), LRD(100), LID(100), LIDD(100), RM1(100), NRM1(100), RM3(100),
     9NRM3(100), ROAS(100), NROAS(100)
C
C     THIS SECTION READS & WRITES THE INPUT DATA AND TERMINATES THE
C     PROGRAM IN CASES OF INSUFFICIENT INFORMATION.
      QDEV=0.D0
      QCARD=0.D0
      QNG=0.D0
      QGATE=0.D0
      READ (1,*) N,NC,FSTD,CMAX,CMIN,RATEE2,RATET4,RATE1,RATE2,RATE3,M,T
     1S,PL,TO,TR,FC,D,KI,KIR,KSM,KR,KM,KT,WC,RD,RI,YRDTE,TRDTE,YMANU,TMA
     2NU,YOAS
      IF ((N.LE.0).OR.(NC.LE.0)) GO TO 10
      GO TO 20
10    WRITE (6,420)
      GO TO 410
20    CONTINUE
      DO 30 I=1,N
      READ (2,*) NEW(I),MEM(I),MOS(I),DIG(I),ECL(I),FP(I),NG(I),NB(I),NP
     1(I),DEVQ(I),REL(I),SCRN(I)
30    CONTINUE
      DO 40 I=1,NC
      READ (3,*) CARD(I),NDEV(I),NMC(I),NDG(I),NLG(I),NRAM(I),W(I),CF(I)
     1,KA(I),KS(I)
40    CONTINUE
      DO 50 I=1,N
      IF ((MEM(I).LT.0.D0).OR.(ECL(I).LT.0.D0).OR.(NEW(I).LT.0.D0).OR.(R
     1EL(I).LE.0.D0).OR.(NG(I).LT.0.D0).OR.(NB(I).LT.0.D0).OR.(DEVQ(I).L
     2E.0.D0).OR.(NP(I).LT.0.D0)) GO TO 70
50    CONTINUE
      DO 60 I=1,NC
      IF ((CARD(I).LE.0.D0).OR.(NDEV(I).LE.0.D0).OR.(NMC(I).LE.0.D0).OR.
     1(NDG(I).LT.0.D0).OR.(CF(I).LE.0.D0)) GO TO 70
60    CONTINUE
      GO TO 120
70    WRITE (6,430)
80    WRITE (6,500)
      WRITE (6,520) N,M,KR,NC,TS,KM,FSTD,PL,KT,CMAX,TO,WC,CMIN,TR,RD,RAT
     1EE2,FC,RI,RATET4,D,YRDTE,RATE1,KI,TRDTE,RATE2,KIR,YMANU,RATE3,KSM,
     2TMANU,YOAS
      WRITE (6,570)
      WRITE (6,530)
      DO 90 I=1,N
```

```
      WRITE (6,540) I,NEW(I),MEM(I),MOS(I),DIG(I),ECL(I),FP(I),NG(I),NB(
     1I),NP(I),DEVQ(I),REL(I),SCRN(I)
   90 CONTINUE
      WRITE (6,590)
      WRITE (6,580)
      WRITE (6,550)
      DO 100 I=1,NC
      WRITE (6,560) I,CARD(I),NDEV(I),NMC(I),QA(I),QB(I),QB1(I),QB2(I),Q
     1CD(I),NDG(I),NLG(I),NRAM(I),W(I),CF(I),KA(I),KS(I)
  100 CONTINUE
      WRITE (6,600)
      IF (QCARD.EQ.QDEV) GO TO 110
      WRITE (6,610) QDEV,QCARD
  110 CONTINUE
      IF (QNG.EQ.QGATE) GO TO 410
      WRITE (6,620) QNG,QGATE
      GO TO 410
  120 CONTINUE
      IF (RI.LE.0.D0) RI=0.06D0
      IF (RD.LE.0.D0) RD=0.1D0
      IF (M.LE.0.D0) M=1.D0
      IF (YRDTE.LE.0) YRDTE=1980
      IF (TRDTE.LE.0) TRDTE=0
      IF (TMANU.LE.0) TMANU=1
      IF (YMANU.LE.0) GO TO 140
  130 IF (YOAS.LE.0) GO TO 150
      GO TO 160
  140 YMANU=YRDTE+TRDTE
      GO TO 130
  150 YOAS=YMANU+TMANU
  160 CONTINUE
      FACIM=(1.D0+RI)**(YRDTE-1980)
C
C     THIS SECTION COMPUTES TOTAL RDT&E COST FOR ALL TYPES OF
C     NEW DEVICES TO BE USED.
      RDTES=0.D0
      IF (FSTD.LE.0.D0) FSTD=0.D0
      IF (CMAX.LE.0.D0) GO TO 190
  170 IF (CMIN.LE.0.D0) GO TO 200
  180 FSTDC=(CMIN-CMAX)*FSTD+CMAX
      GO TO 210
  190 CMAX=203.D0*FACIM
      GO TO 170
  200 CMIN=24.D0*FACIM
      GO TO 180
  210 CONTINUE
      IF (TRDTE.EQ.0) GO TO 240
      DO 230 I=1,N
      IF (NEW(I).EQ.0.D0) GO TO 220
      CALL XRDTE (NG(I),FSTDC,RDTEF)
      RDTES=RDTES+RDTEF
  220 CONTINUE
  230 CONTINUE
      RDTES=RDTES/(1000.D0*TRDTE)
      CALL IRND (RDTES)
```

```
      RDTES=RDTES*TRDTE
240   CONTINUE
C
C     THIS SECTION COMPUTES THE TOTAL PURCHASE PRICE FOR THE TOTAL
C     QUANTITY OF DEVICES.
      PURCHS=0.D0
      DNEW=0.D0
      DO 250 I=1,N
      DNEW=DNEW+NEW(I)
      CALL XPURCH (MEM(I),DIG(I),ECL(I),MOS(I),FP(I),REL(I),NG(I),NB(I),
     1PURCHF)
      PURCHS=PURCHS+PURCHF*DEVQ(I)
250   CONTINUE
      PURCHS=(1.25D0*PURCHS*FACIM)/(1000.D0*TMANU)
      CALL IRND (PURCHS)
      PURCHS=PURCHS*TMANU
C
C     THIS SECTION ESTIMATES THE PROPORTIONAL DISTRIBUTION OF MC'S,
C     QUALITY GRADES A,B,B1,B2 AND BELOW ON A CARD.
      EQA=0.D0
      EQB=0.D0
      EQB1=0.D0
      EQB2=0.D0
      EQCD=0.D0
      ERA=0.D0
      DO 260 I=1,N
      IF (SCRN(I).LE.0.D0) SCRN(I)=2.D0
      CALL XQLTY (REL(I),DEVQ(I),EQA,EQB,EQB1,EQB2,EQCD,SCRN(I))
      QDEV=QDEV+DEVQ(I)
      QNG=QNG+NG(I)*DEVQ(I)
260   CONTINUE
      FQA=EQA/QDEV
      FQB=EQB/QDEV
      FQB1=EQB1/QDEV
      FQB2=EQB2/QDEV
      FQCD=EQCD/QDEV
C
C     THIS SECTION COMPUTES THE SCREENING TEST COST.
      SCRS=0.D0
      DO 280 I=1,N
      IF (SCRN(I).EQ.1.D0) GO TO 270
      CALL XSCR (DEVQ(I),MEM(I),MOS(I),NP(I),NG(I),RATEE2,RATET4,FACIM,N
     1EW(I),SCREEN)
      SCRS=SCRS+SCREEN
270   CONTINUE
280   CONTINUE
      SCRS=SCRS/(1000.D0*TMANU)
      CALL IRND (SCRS)
      SCRS=SCRS*TMANU
C
C     THIS SECTION COMPUTES TOTAL CARD ASSEMBLY COSTS FOR THE
C     TOTAL QUANTITY OF CARDS.
      ASSYS=0.D0
      TCP=0.D0
      MANUS=0.D0
```

```
      DO 290 I=1,NC
      IF (W(I).LE.0.D0) W(I)=1.D0
      TCP=TCP+CARD(I)
      CALL CASSY (NDEV(I),NRAM(I),CASSYS(I))
      ASSYS=ASSYS+1.25D0*FACIM*CASSYS(I)*CARD(I)
C
C     THIS SECTION COMPUTES MANUFACTURING COSTS FOR
C     THE TOTAL QUANTITY OF CARDS.
      QCARD=QCARD+CARD(I)*NMC(I)
      QGATE=QGATE+(NLG(I)+NDG(I))*CARD(I)
      QA(I)=FQA*NMC(I)
      CALL IRND (QA(I))
      QB(I)=FQB*NMC(I)
      CALL IRND (QB(I))
      QB1(I)=FQB1*NMC(I)
      CALL IRND (QB1(I))
      QB2(I)=FQB2*NMC(I)
      CALL IRND (QB2(I))
      XQB2(I)=(FQB2+FQCD*2.82692D0)*NMC(I)
      CALL IRND (XQB2(I))
      QCD(I)=FQCD*NMC(I)
      CALL IRND (QCD(I))
      CALL CTHRS (NDEV(I),NDG(I),W(I),NLG(I),NMC(I),H(I))
      IF (H(I).LE.0.5D0) H(I)=0.5D0
      CALL XC1 (H(I),RATE1,FACIM,C1)
      CALL XC2 (RATE2,FACIM,C2)
      CALL XC3 (RATE3,FACIM,C3)
      CALL XYS (NDEV(I),NMC(I),YS(I))
      CALL XYC (NMC(I),NDEV(I),XQB2(I),NLG(I),W(I),YC(I))
      CALL PROD (C1,C2,C3,YC(I),YS(I),PRODF(I))
      MANUS=MANUS+PRODF(I)*CARD(I)
      CARDS(I)=((PURCHS+SCRS)/QDEV)*NMC(I)+1.25D0*FACIM*CASSYS(I)+PRODF(
     1I)
290   CONTINUE
      MANUS=MANUS+ASSYS
      MANUS=MANUS/(1000.D0*TMANU)
      CALL IRND (MANUS)
      MANUS=MANUS*TMANU
      PRS=PURCHS+MANUS+SCRS
      KCARD=PRS*1000.D0/TCP
C     THIS SECTION COMPUTES MAJOR MAINTENANCE AND SUPPORT COSTS.
      RM1L=0.D0
      NRM1L=0.D0
      MCER2L=0.D0
      RM3L=0.D0
      NRM3L=0.D0
      MCER4L=0.D0
      MCER5L=0.D0
      MCER6L=0.D0
      IF (TO.LE.0.D0) TO=8760.D0
      IF (FC.LE.0.D0) FC=0.D0
      DO 300 I=1,NC
      CALL XMCER1 (NC,M,X,TS,PL,CARDS(I),CARD(I),TO,TR,CF(I),W(I),FC,D,J
     1,RM1F,NRM1F)
      RM1L=RM1L+RM1F
```

```
      NRM1L=NRM1L+NRM1F                                                 MAIN2210
      CALL XMCER2 (KA(I),KS(I),MCER2F)                                  MAIN2220
      MCER2L=MCER2L+MCER2F                                              MAIN2230
      CALL XMCER4 (CARD(I),KR,TO,CF(I),W(I),H(I),FC,FACIM,NLG(I),NDG(I),MAIN2240
     1MCER4F)                                                           MAIN2250
      MCER4L=MCER4L+MCER4F                                              MAIN2260
      CALL XMCER5 (CARD(I),TO,CF(I),W(I),KM,KCARD,MCER5F)               MAIN2270
      MCER5L=MCER5L+MCER5F                                              MAIN2280
      CALL XMCER6 (CARD(I),WC,TO,KT,FACIM,CF(I),W(I),FC,MCER6F)         MAIN2290
      MCER6L=MCER6L+MCER6F                                              MAIN2300
  300 CONTINUE                                                          MAIN2310
      CALL XMCER3 (NC,DNEW,M,KI.KIR,KSM,FACIM,RM3L,NRM3L)               MAIN2320
      RM1L=RM1L/1000.D0                                                 MAIN2330
      CALL IRND (RM1L)                                                  MAIN2340
      NRM1L=NRM1L/1000.D0                                               MAIN2350
      CALL IRND (NRM1L)                                                 MAIN2360
      MCER2L=MCER2L/1000.D0                                             MAIN2370
      CALL IRND (MCER2L)                                                MAIN2380
      RM3L=RM3L/1000.D0                                                 MAIN2390
      CALL IRND (RM3L)                                                  MAIN2400
      NRM3L=NRM3L/1000.D0                                               MAIN2410
      CALL IRND (NRM3L)                                                 MAIN2420
      MCER4L=MCER4L/1000.D0                                             MAIN2430
      CALL IRND (MCER4L)                                                MAIN2440
      MCER5L=MCER5L/1000.D0                                             MAIN2450
      CALL IRND (MCER5L)                                                MAIN2460
      MCER6L=MCER6L/1000.D0                                             MAIN2470
      CALL IRND (MCER6L)                                                MAIN2480
      Y=5                                                               MAIN2490
  310 RM1(Y)=Y*RM1L                                                     MAIN2500
      NRM1(Y)=NRM1L                                                     MAIN2510
      MCER1(Y)=RM1(Y)+NRM1(Y)                                           MAIN2520
      MCER2(Y)=MCER2L                                                   MAIN2530
      RM3(Y)=Y*RM3L                                                     MAIN2540
      NRM3(Y)=NRM3L                                                     MAIN2550
      MCER3(Y)=RM3(Y)+NRM3(Y)                                           MAIN2560
      MCER4(Y)=MCER4L*Y                                                 MAIN2570
      MCER5(Y)=MCER5L*Y                                                 MAIN2580
      MCER6(Y)=Y*MCER6L                                                 MAIN2590
      ROAS(Y)=RM1(Y)+RM3(Y)+MCER4(Y)+MCER5(Y)+MCER6(Y)                  MAIN2600
      NROAS(Y)=NRM1(Y)+NRM3(Y)+MCER2(Y)                                 MAIN2610
      OAS(Y)=MCER1(Y)+MCER2(Y)+MCER3(Y)+MCER4(Y)+MCER5(Y)+MCER6(Y)      MAIN2620
      TOTALC(Y)=RDTES+PRS+OAS(Y)                                        MAIN2630
      IF (Y.GE.15) GO TO 320                                            MAIN2640
      Y=Y+5                                                             MAIN2650
      GO TO 310                                                         MAIN2660
  320 CONTINUE                                                          MAIN2670
C                                                                       MAIN2680
C     THIS SECTION CALCULATES THE LCC SUMMARY BY FISCAL YEAR.           MAIN2690
      YRDTE=YRDTE-1980                                                  MAIN2700
      YMANU=YMANU-1980                                                  MAIN2710
      YOAS=YOAS-1980                                                    MAIN2720
      IYOAS=YOAS+14                                                     MAIN2730
      DO 330 I=YRDTE,IYOAS                                              MAIN2740
      RDTE(I)=0.D0                                                      MAIN2750
```

```
      LINV(I)=0.D0
      LOAS(I)=0.D0
  330 CONTINUE
      IF (TRDTE.EQ.0) GO TO 350
      IYRDTE=YRDTE+TRDTE-1
      DO 340 I=YRDTE,IYRDTE
      RDTE(I)=RDTES/TRDTE
  340 CONTINUE
  350 CONTINUE
      IYMAN=YMANU+TMANU-1
      DO 360 I=YMANU,IYMAN
      LINV(I)=(PRS)/TMANU
  360 CONTINUE
      DO 370 I=YOAS,IYOAS
      LOAS(I)=ROAS(15)/15.D0
  370 CONTINUE
      LOAS(YOAS)=LOAS(YOAS)+NROAS(15)
      RDFAC=DLOG(1.D0+RD)
      TOTRAD=0.D0
      TOTINV=0.D0
      TOTOAS=0.D0
      TOTC=0.D0
      TOTI=0.D0
      TOTIAD=0.D0
      DO 380 I=YRDTE,IYOAS
      CALL IRND (RDTE(I))
      CALL IRND (LINV(I))
      CALL IRND (LOAS(I))
      TOTRAD=TOTRAD+RDTE(I)
      TOTINV=TOTINV+LINV(I)
      TOTOAS=TOTOAS+LOAS(I)
      LTOTAL(I)=RDTE(I)+LINV(I)+LOAS(I)
      CALL IRND (LTOTAL(I))
      TOTC=TOTC+LTOTAL(I)
      LRI(I)=(1.D0+RI)**(I-YRDTE)
      LID(I)=LTOTAL(I)*LRI(I)
      CALL IRND (LID(I))
      TOTI=TOTI+LID(I)
      LRD(I)=RD/(RDFAC*(1.D0+RD)**(I+1))
      LIDD(I)=LID(I)*LRD(I)
      CALL IRND (LIDD(I))
      TOTIAD=TOTIAD+LIDD(I)
  380 CONTINUE
      YRDTE=YRDTE+1980
      YMANU=YMANU+1980
      YOAS=YOAS+1980
C
C     THIS SECTION PRINTS THE RESULTS OF THE LCC STUDY.
      WRITE (6,510)
      WRITE (6,450)
      WRITE (6,440)
      WRITE (6,460) RDTES,RDTES,RDTES,PRS,PRS,PRS,PURCHS,PURCHS,PURCHS,S
     1CRS,SCRS,SCRS,MANUS,MANUS,MANUS,OAS(5),OAS(10),OAS(15),MCER1(5),MC
     2ER1(10),MCER1(15),MCER2(5),MCER2(10),MCER2(15),MCER3(5),MCER3(10),
     3MCER3(15),MCER4(5),MCER4(10),MCER4(15),MCER5(5),MCER5(10),MCER5(15
```

```
     4),MCER6(5),MCER6(10),MCER6(15),TOTALC(5),TOTALC(10),TOTALC(15)
      WRITE (6,470)
      I=YRDTE-1980
      INDEX=YRDTE
390   WRITE (6,480) INDEX,RDTE(I),LINV(I),LOAS(I),LTOTAL(I),LRI(I),LID(I
     1),LRD(I),LIDD(I)
      IF (I.GE.IYOAS) GO TO 400
      I=I+1
      INDEX=INDEX+1
      GO TO 390
400   WRITE (6,490) TOTRAD,TOTINV,TOTOAS,TOTC,TOTI,TOTIAD
      GO TO 80
410   STOP
C
420   FORMAT (///1X,'PROGRAM TERMINATED DUE TO INSUFFICIENT DATA.',1X,'T
     1HE NUMBER OF DISTINCT DEVICE TYPES AND THE NUMBER OF DISTINCT CARD
     2 TYPES ARE ESSENTIAL TO RUN THE PROGRAM.'/)
430   FORMAT (///1X,'PROGRAM TERMINTED DUE TO INSUFFICIENT DATA.'/)
440   FORMAT (4X,'COST ELEMENT',15X,'5 YEARS',7X,'10 YEARS',7X,'15 YEARS
     1'/1X,'-----------------------------------------------------------
     2----------'/)
450   FORMAT (42X,'CONSTANT DOLLARS'/30X,'------------------------------
     1-----------')
460   FORMAT (1X,'RDT&E',17X,3(F15.0)//1X,'PRODUCTION',12X,3(F15.0)/2X,'
     1DEVICE PROCUREMENT',3X,3(F15.0)/2X,'DEVICE SCREEN',8X,3(F15.0)/2X,
     2'CARD ASSEMBLY',8X,3(F15.0)//1X,'OPERATIONS & SUPPORT',2X,3(F15.0)
     3/1X,' SPARES',15X,3(F15.0)/1X,' SUPPORT EQUIPTMENT',3X,3(F15.0)/1X
     4,' INVENTORY ENTRY',6X,3(F15.0)/1X,' REPAIR LABOR',9X,3(F15.0)/1X,
     5' REPAIR MATERIALS',5X,3(F15.0)/1X,' MAIN. TRANSPORTATION',1X,3(F1
     65.0)//1X,'-------------------------------------------------------
     7-------------'/1X,'TOTAL COST',12X,3(F15.0)/////)
470   FORMAT (12X,'LCC SUMMARY BY FISCAL YEAR (THOUSANDS OF DOLLARS)'/1X
     1,'---------------------------------------------------------------
     2------------------'/1X,'FISCAL',8X,'PROGRAM PHASE',8X,'TOTAL',6X,'
     3PRICE',3X,'INFLATED',4X,'DISC.',6X,'TOTAL'/1X,'YEAR',5X,'RDT&E',4X
     4,'PROD',6X,'O&S',4X,'DOLLARS',4X,'INDEX',4X,'DOLLARS',4X,'FACT.',6
     5X,'COST'/1X,'-----------------------------------------------------
     6----------------------------'/)
480   FORMAT (1X,I4,4(1X,F8.0),3X,2(1X,F7.3,2X,F9.0))
490   FORMAT (/1X,'-----------------------------------------------------
     1---------------------------'/1X,'TOTAL',4(F8.0,1X),7X,F14.0,5X,F1
     24.0/////)
500   FORMAT (/26X,'DATA USED IN LCC ESTIMATE:'//30X,'PROGRAM & O&S DATA
     1'/1X,'-----------------------------------------------------------
     2---------------------')
510   FORMAT (///12X,'MC DEVICE IMPACT ON LCC (THOUSANDS OF DOLLARS)'/1X
     1,'---------------------------------------------------------------
     2-------')
520   FORMAT (1X,'N',I17,15X,'M',F14.0,15X,'KR',F15.2/1X,'NC',I16,15X,'T
     1S',F13.0,15X,'KM',F15.2/1X,'FSTD',F14.2,15X,'PL',F13.2,15X,'KT',F1
     25.2/1X,'CMAX',F14.2,15X,'TO',F13.0,15X,'WC',F15.2/1X,'CMIN',F14.2,
     315X,'TR',F13.0,15X,'RO',F15.2/1X,'RATE4',F13.2,15X,'FC',F13.0,15X,
     4'RI',F15.2/1X,'RATE5',F13.2,15X,'D',F14.2,15X,'YRDTE',I12/1X,'RATE
     51',F13.2,15X,'KI',F13.2,15X,'TRDTE',I12/1X,'RATE2',F13.2,15X,'KIR'
     6,F12.2,15X,'YMANU',I12/1X,'RATE3',F13.2,15X,'KSM',F12.2,15X,'TMANU
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     7',I1./64X,'YOAS',I13)
530   FORMAT (3X,'I',2X,'NEW',2X,'MEM',2X,'MOS',2X,'DIG',2X,'ECL',3X,'FP
     1',5X,'NG',7X,'NB',3X,'NP',3X,'DEVQ*',4X,'REL',1X,'SCRN')
540   FORMAT (1X,I3,6(2X,F3.0),2(1X,F7.0),2X,F4.0,2X,F6.0,2X,F4.1,1X,F4.
     10)
550   FORMAT (3X,'I',2X,'CARD*',2X,'NDEV',4X,'NMC',3X,'QA',3X,'QB',2X,'Q
     1B1',2X,'QB2',2X,'QCD',4X,'NDG',5X,'NLG',2X,'NRAM',2X,'W',7X,'CF',6
     2X,'KA',5X,'KS')
560   FORMAT (1X,I3,1X,F5.0,2(1X,F6.0),5(1X,F4.0),2(1X,F7.0),1X,F4.0,1X,
     1F4.2,1X,F8.7,2(1X,F6.0))
570   FORMAT (//35X,'MC DEVICE DATA'/1X,'-------------------------------
     1------------------------------------------------')
580   FORMAT (//35X,'CARD DATA'/1X,'------------------------------------
     1-------------------------------------------------------------')
590   FORMAT (1X,'* TOTAL QUANTITY OF MC DEVICES.')
600   FORMAT (1X,'* TOTAL QUANTITY OF CARDS.'/)
610   FORMAT (1X,'NOTE: THE QUANTITY OF MC DEVICES AT THE DEVICE LEVEL D
     1OES NOT AGREE WITH THE QUANTITY OF MC DEVICES AT THE CARD LEVEL.
     2 '/1X,'QTY @ DEVICE LEVEL:',F10.0/1X,'QTY @ CARD LEVEL:',F12.0///)
620   FORMAT (1X,'NOTE: THE TOTAL QUANTITY OF GATES AT THE DEVICE LEVEL
     1DOES NOT EQUAL THE TOTAL QUANTITY OF GATES AT THE CARD LEVEL.'/1X,
     2'QTY @ DEVICE LEVEL:',F15.0/1X,'QTY @ CARD LEVEL:',F17.0///)
      END
C     THIS SECTION SUPPLIES THE SUBROUTINES FOR THE MODEL. FORMULATED
C     DEFAULT CERS ARE IMPLEMENTED WHEN PIECES OF INFORMATION
C     ARE MISSING. CER'S FOR THE MAIN PROGRAM ARE SUPPLIED IN THIS
C     SECTION.
C
      SUBROUTINE XRDTE (NG,FSTDC,RDTEF)
C     THIS SUBROUTINE PREDICTS THE COST OF RDT&E FOR
C     NEW DEVICES, RCER.
      IMPLICIT REAL*8(A-H,J-Z)
      RDTEF=NG*FSTDC
      RETURN
      END
      SUBROUTINE XPURCH (MEM,DIG,ECL,MOS,FP,R,NG,NB,PURCHF)
C     THIS SUBROUTINE PREDICTS THE PURCHASE COST FOR
C     ANY GIVEN DEVICE, PCER1.
      IMPLICIT REAL*8(A-H,J-Z)
      INTEGER X,Y,NC,N
      IF (NG.GT.0.D0) GO TO 10
      RG=0.D0
      RB=R/NB
      GO TO 20
10    RG=R/NG
      RB=0.D0
20    CONTINUE
      IF (MOS.LT.0.D0) GO TO 30
      IF (FP.LT.0.D0) GO TO 40
      IF (DIG.LT.0.D0) GO TO 50
      GO TO 60
30    PURCHF=DEXP(0.29312D0+1.69924D0*MEM+1.65570D0*ECL-0.23799D0*RG-9.2
     19049D0*RB)
      RETURN
40    PURCHF=DEXP(0.29528D0+1.90967D0*MEM+1.66451D0*ECL-3.00344D0*MOS-0.
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      1238[illegible]D0*RG-11.3544D00*RB)
      RETURN
50    PURCHF=DEXP(0.02207D0+1.84461D0*MEM+1.58816D0*ECL-2.66517D0*MOS+0.
     160918D0*FP-0.20841D0*RG-9.15497D0*RB)
      RETURN
60    PURCHF=DEXP(0.52165D0+1.38197D0*MEM-0.69142D0*DIG+1.84202D0*ECL-2.
     170211D0*MOS+0.56445D0*FP-0.22443D0*RG-9.83248D0*RB)
      RETURN
      END
      SUBROUTINE CASSY (NDEV,NRAM,CASSYS)
C     THIS SUBROUTINE COMPUTES CARD ASSEMBLY COST, PCER3.
      IMPLICIT REAL*8(A-H,J-Z)
      IF (NRAM.LT.0.D0) GO TO 10
      CASSYS=5.91634D0*NDEV+27.57201D0*NRAM
      RETURN
10    CASSYS=6.26267D0*NDEV
      RETURN
      END
      SUBROUTINE XSCR (DEVQ,MEM,MOS,NP,NG,RATEE2,RATET4,FACIM,NEW,SCREEN
     1)
C     THIS SUBROUTINE COMPUTES THE COST OF PERFORMING THE
C     SCREENING TEST, PCER2.
      IMPLICIT REAL*8(A-H,J-Z)
      IF (RATEE2.LE.0.D0) GO TO 90
10    IF (RATET4.LE.0.D0) GO TO 100
20    IF ((MEM.EQ.1.D0).AND.((NP.GE.15.D0).AND.(NP.LT.24.D0))) GO TO 50
      IF ((NP.GE.0.D0).AND.(NP.LT.17.D0).AND.(NG.GE.10.D0).AND.(NG.LE.1
     10.D0)) GO TO 30
      IF ((NP.GE.24.D0).AND.(NG.GE.100.D0)) GO TO 70
      GO TO 50
30    SCREEN=(.01917D0*RATEE2+.431D0*RATET4)*DEVQ
      IF (NEW.EQ.1.D0) GO TO 40
      RETURN
40    SCREEN=SCREEN+20.D0*RATEE2
      RETURN
50    SCREEN=(0.05417D0*RATEE2+0.621D0*RATET4+13.75D0*FACIM)*DEVQ+40.D0*
     1RATEE2
      IF (NEW.EQ.1.D0) GO TO 60
      RETURN
60    SCREEN=SCREEN+80.D0*RATEE2
      RETURN
70    SCREEN=(0.12417D0*RATEE2+1.211D0*RATET4+72.D0*FACIM)*DEVQ+160.D0*R
     1ATEE2
      IF (NEW.EQ.1.D0) GO TO 80
      RETURN
80    SCREEN=SCREEN+180.D0*RATEE2
      RETURN
90    RATEE2=43.75D0*FACIM
      GO TO 10
100   RATET4=35.D0*FACIM
      GO TO 20
      END
      SUBROUTINE CTHRS (NDEV,NDG,W,NLG,NMC,H)
C     THIS SUBROUTINE IMPLEMENTS THE CARD TEST HOURS CER, H.
      IMPLICIT REAL*8(A-H,J-Z)
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      IF (NLG.LT.0.D0) GO TO 10                                         CTHR
      H=-0.29669D0+0.00000889D0*NDEV*NDG+4.99908D0*(1.D0-W)+0.01514D0*NLCTHR
     1G+1.98307D0*(NMC/NDEV)**2                                         CTHR
      RETURN                                                            CTHR
   10 H=0.37016D0+0.00000891D0*NDEV*NDG+5.13788D0*(1.D0-W)              CTHR
      RETURN                                                            CTHR
      END                                                               CTHR
      SUBROUTINE XC1 (H,RATE1,FACIM,C1)                                 XC1
C     THIS SUBROUTINE COMPUTES C1, WHICH IS USED IN                     XC1
C     LATER CALCULATIONS.                                               XC1
      IMPLICIT REAL*8(A-H,J-Z)                                          XC1
      IF (RATE1.LE.0.D0) GO TO 20                                       XC1
   10 C1=RATE1*H                                                        XC1
      RETURN                                                            XC1
   20 RATE1=26.9D0*FACIM                                                XC1
      GO TO 10                                                          XC1
      END                                                               XC1
      SUBROUTINE XC2 (RATE2,FACIM,C2)                                   XC2
C     THIS SUBROUTINE COMPUTES C2, WHICH IS USED IN                     XC2
C     LATER CALCULATIONS.                                               XC2
      IMPLICIT REAL*8(A-H,J-Z)                                          XC2
      IF (RATE2.LE.0.D0) GO TO 20                                       XC2
   10 C2=RATE2*0.5D0                                                    XC2
      RETURN                                                            XC2
   20 RATE2=26.9D0*FACIM                                                XC2
      GO TO 10                                                          XC2
      END                                                               XC2
      SUBROUTINE XC3 (RATE3,FACIM,C3)                                   XC3
C     THIS SUBROUTINE COMPUTES C3, WHICH IS USED IN LATER               XC3
C     CALCULATIONS.                                                     XC3
      IMPLICIT REAL*8(A-H,J-Z)                                          XC3
      IF (RATE3.LE.0.D0) GO TO 20                                       XC3
   10 C3=RATE3*0.26D0                                                   XC3
      RETURN                                                            XC3
   20 RATE3=20.3D0*FACIM                                                XC3
      GO TO 10                                                          XC3
      END                                                               XC3
      SUBROUTINE XYS (NDEV,NMC,YS)                                      XYS
C     THIS SUBROUTINE COMPUTES THE SYSTEMS TEST YIELD, YS.              XYS
      IMPLICIT REAL*8(A-H,J-Z)                                          XYS
      YS=DEXP(-0.00094D0*NDEV-0.001D0*NMC)                              XYS
      RETURN                                                            XYS
      END                                                               XYS
      SUBROUTINE XYC (NMC,NDEV,QB2,NLG,W,YC)                            XYC
C     THIS SUBROUTINE IMPLEMENTS THE TEST FRACTIONAL YIELD CER, YC.     XYC
      IMPLICIT REAL*8(A-H,J-Z)                                          XYC
      IF (NLG.LT.0.D0) GO TO 10                                         XYC
      YC=10**(-0.20504D0*(NMC/NDEV)-0.00146D0*QB2-0.00122D0*NLG-0.14842DXYC
     10*(1.D0-W))                                                       XYC
      RETURN                                                            XYC
   10 YC=10**(-0.31298D0*(NMC/NDEV))                                    XYC
      RETURN                                                            XYC
      END                                                               XYC
      SUBROUTINE PROD (C1,C2,C3,YC,YS,PRODF)                            PROD
C     THIS SUBROUTINE PREDICTS THE MANUFACTURING COSTS                  PROD
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C     FOR ANY CARD TYPE, PCER4.
      IMPLICIT REAL*8(A-H,J-Z)
      PRODF=(C1+C2*YC+C3*(1.D0-YC*YS))/(YC*YS)
      RETURN
      END
      SUBROUTINE XMCER1 (NC,M,X,TS,PL,CARDS,CARD,TO,TR,CF,W,FC,D,J,RM1F,
     1NRM1F)
C     THIS SUBROUTINE COMPUTES THE INITIAL STOCK AND PIPELINE
C     PLUS REPLENISHMENT CER, MCER1.
      IMPLICIT REAL*8(A-H,K-Z)
      INTEGER X,N,NC
      IF (TS.LE.0.D0) TS=336.D0
      IF (TR.LE.0.D0) TR=1440.D0
      IF (D.LE.0.D0) D=0.05D0
      IF (PL.LE.0.D0) PL=0.9D0
      KC=CARDS
      QC=CARD/M
      X=0
      A=TS*QC*CF*(1.D0+FC)
      PROB=PL**(1.D0/NC)
      SUM=DEXP(-A)
      IF (SUM.GE.PROB) GO TO 30
      TERM=SUM
      J=1
10    TERM=TERM*(A/J)
      SUM=SUM+TERM
      IF (SUM.GE.PROB) GO TO 20
      J=J+1
      GO TO 10
20    X=J
30    MULT=TO*QC*CF*(1.D0+FC)
      RM1F=W*D*MULT*KC*M
      NRM1F=M*KC*(X+(TR/8760.D0)*MULT)
      RETURN
      END
      SUBROUTINE XMCER2 (KA,KS,MCER2F)
C     THIS SUBROUTINE COMPUTES THE SUPPORT EQUIPTMENT CER, MCER2.
      IMPLICIT REAL*8(A-H,J-Z)
      IF (KA.LE.0.D0) KA=0.D0
      IF (KS.LE.0.D0) KS=0.D0
      MCER2F=KA+KS
      RETURN
      END
      SUBROUTINE XMCER3 (NC,DNEW,M,KI,KIR,KSM,FACIM,RM3L,NRM3L)
C     THIS SUBROUTINE COMPUTES THE INVENTORY ENTRY
C     OF SUPPLY MANAGEMENT CER, MCER3.
      IMPLICIT REAL*8(A-H,J-Z)
      INTEGER N,NC
      IF (KI.LT.0.D0) GO TO 40
10    IF (KIR.LT.0.D0) GO TO 50
20    IF (KSM.LT.0.D0) GO TO 60
30    IF (KI.EQ.0.D0) KIR=0.D0
      IF (KIR.EQ.0.D0) KI=0.D0
      RM3L=((DNEW+NC+1)*KIR+M*NC*KSM)
      NRM3L=(DNEW+NC+1)*KI
```

```
      RETURN
40    KI=54.D0*FACIM
      GO TO 10
50    KIR=128.D0*FACIM
      GO TO 20
60    KSM=42.D0*FACIM
      GO TO 30
      END
      SUBROUTINE XMCER4 (CARD,KR,TO,CF,W,H,FC,FACIM,NLG,NDG,MCER4F)
C     THIS SUBROUTINE COMPUTES THE REPAIR LABOR CER, MCER4.
      IMPLICIT REAL*8(A-H,J-Z)
      IF (KR.LE.0.D0) GO TO 20
      LF=1.5D0
      IF (NLG.GT.NDG) LF=3.D0
10    MCER4F=KR*TO*CARD*W*CF*(0.26D0+H+LF*FC)
      RETURN
20    KR=20.D0*FACIM
      GO TO 10
      END
      SUBROUTINE XMCER5 (CARD,TO,CF,W,KM,CARDS,MCER5F)
C     THIS SUBROUTINE COMPUTES THE REPAIR MATERIALS
C     COST CER, MCER5
      IMPLICIT REAL*8(A-H,J-Z)
      INTEGER N,NC
      IF (KM.LE.0.D0) GO TO 20
10    MCER5F=TO*CARD*W*CF*KM
      RETURN
20    KM=0.05D0*CARDS
      GO TO 10
      END
      SUBROUTINE XMCER6 (CARD,WC,TO,KT,FACIM,CF,W,FC,MCER6F)
C     THIS SUBROUTINE COMPUTES THE MAINTENANCE
C     TRANSPORTATION COST CER, MCER6.
      IMPLICIT REAL*8(A-H,J-W)
      INTEGER N,NC
      IF (WC.LE.0.D0) WC=1.D0
      IF (KT.LE.0.D0) GO TO 20
10    MCER6F=2.D0*WC*TO*CARD*CF*W*(1.D0+FC)*KT
      RETURN
20    KT=0.5D0*FACIM
      GO TO 10
      END
      SUBROUTINE XQLTY (REL,DEVQ,EQA,EQB,EQB1,EQB2,EQCD,SCRN)
C     THIS SUBROUTINE ESTIMATES THE QUANTITIES OF MC'S,
C     QUALITY GRADES A,B,B1,B2,AND BELOW FROM
C     THE DEVICE RELIABILITIES.
      IMPLICIT REAL*8(A-H,K-Z)
      IF (REL.EQ.0.5D0) GO TO 10
      IF (REL.EQ.1.D0) GO TO 20
      IF ((REL.EQ.3.0D0).OR.((REL.GE.6.5D0).AND.(SCRN.EQ.2.D0))) GO TO 3
     10
      IF (REL.EQ.6.5D0) GO TO 40
      EQCD=EQCD+DEVQ
      RETURN
10    EQA=EQA+DEVQ
```

```
      RETURN
20    EQB=EQB+DEVQ
      RETURN
30    EQB1=EQB1+DEVQ
      RETURN
40    EQB2=EQB2+DEVQ
      RETURN
      END
      SUBROUTINE IRND (A)
C     THIS SUBROUTINE ROUNDS THE LCC ESTIMATES TO THE NEAREST INTEGER.
      REAL*8 A,B
      IRNDS=A
      B=DFLOAT(IRNDS)
      IF (A-B.GE.0.5D0) IRNDS=IRNDS+1
      A=DFLOAT(IRNDS)
      RETURN
      END
```

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